THE BOTANY OF CROP PLANTS

A TEXT AND REFERENCE BOOK

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WITH 263 ILLUSTRATIONS

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PREFACE TO SECOND EDITION

Since the first edition of this volume was issued, there have been many contributions to our knowledge of the botany of crop plants, which have made additions and alterations in the text necessary. The inclusion of these changes has not altered the organization of subject matter, or added materially to the size of the volume, but it has aimed to bring the text up-to-date.

A few new illustrations have been added. Most of the maps giving acreage and production of crops have also been brought up to date by the substitution of those giving data issued by the U. S. Department of Agriculture in 1921, which are based largely on the 1920 census.

In the preface to the first edition, the writer spoke of the growing tendency wherever botany is taught to make use of crop plants as objects of study. One who has watched the development in the last few years of botanical courses in universities, colleges and high schools cannot escape noticing that this tendency is still very marked.

Acknowledgments are due to Professors Ernst Bessey, J. F. Duggar, Henry Jones, E. J. Kraus, Francis Ramaley, J. T. Rosa, and A. H. Wright for valuable suggestions given in the preparation of various portions of this edition.

PREFACE TO FIRST EDITION

This book has grown out of a course of instruction extending over a number of successive years. Most of the material presented here, except Part I, has been used in mimeographed form in college freshmen classes, not only as a text from which to make assignments, but also as a guide and reference in the laboratory. The issuance of the book has been stimulated in part by the expressed need of a number of schools for a text and reference book which will give the student a knowledge of the botany of common orchard, garden and field crops, and it is the author's wish that the material brought together from many sources and organized in the present form will meet this need, at least in a measure.

It has seemed advisable to include chapters (Part I) which may be needed in some instances to refresh the student's knowledge of certain fundamentals, or prepare him for that which follows in Part II. But in many schools Part II will be preceded by a general course which aims to give the student a survey of the plant kingdom and an acquaintance with the large outstanding facts and principles of botany, and in this case Part I will be omitted. The subject matter of Part II is sufficient for a course of one-half year involving one recitation and two laboratory (5) periods per week.

In the preparation of the book, the writer has had in mind non-agricultural as well as agricultural schools, for it cannot escape notice that there is a growing tendency, wherever botany is taught, to tie it up more closely with economic interests and to draw more and more upon economic plants in citing examples and in choosing objects of study in the laboratory.

The bibliographies are obviously incomplete. Most of the titles were made use of by the writer in the preparation of the manuscript, and to the authors of these he is under obligation. Bailey's Cyclopedia of Horticulture has been indispensable and has been called into use frequently. The writer has also called upon the publications of the United States Department of Agriculture and of the various Experiment Stations. A number of the "keys" are original, many are adapted, and a few are taken verbatim. A majority of the illustrations are original. It is believed that the direct method adopted herein of labeling drawings will appeal to both students and teachers.

Almost all original illustrations, and also those copied or adapted are the work of Mr. N. Lee Foster. The writer is especially indebted to him, not only for the delineation, but for his helpful interest and valued coöperation throughout. Professor D. W. Frear, formerly Associate Professor of Agronomy at the Colorado Agricultural College, now of the North Dakota Experiment Station, is to be given credit for organizing and writing up portions of Chapters IX, XVII, XXX and XXXVIII. The text was planned and outlined by Professor Frear and the undersigned as joint authors, but unavoidable exigencies made it impossible for him to continue his connection as author. The entire manuscript was painstakingly read by Louise Falk Robbins, and her suggestions have added greatly to the accuracy in many places.

W. W. Robbins.

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BOTANY OF CROP PLANTS

PART I

CHAPTER I

THE SEED PLANT BODY

The seed plant body, like the human body, is made up of a number of separate parts or members. In the lowest plant group, the Thallophytes (thallus plants), including algæ (pond scums, sea weeds, etc.), and fungi (molds, mildews, mushrooms, etc.), the plant body is relatively simple; it is not composed of distinct members, such as leaves, stems, roots and flowers. Such a simple, undifferentiated plant body is called a *thallus*. Between the typical thallus of algæ and fungi on the one hand, and the highly complex and well-differentiated body of seed plants on the other, there are many intermediate forms, as for example, among the liverworts (Hepaticæ).

Principal Parts of Seed Plant Body (Fig. 1).—The parts of the plant body may be classified according to the work they do, into two groups: (1) those that carry on *vegetative activity;* and (2) those that carry on *reproductive activity.* In seed plants, the stems, leaves and roots are chiefly concerned with maintaining the life of the individual plant, that is, carrying on the vegetative (nutritive) functions, such as absorption of materials from the soil, manufacture of foods, respiration, transpiration, etc., while the flowers which produce seeds, carry on, for the most part, the reproductive activities, and

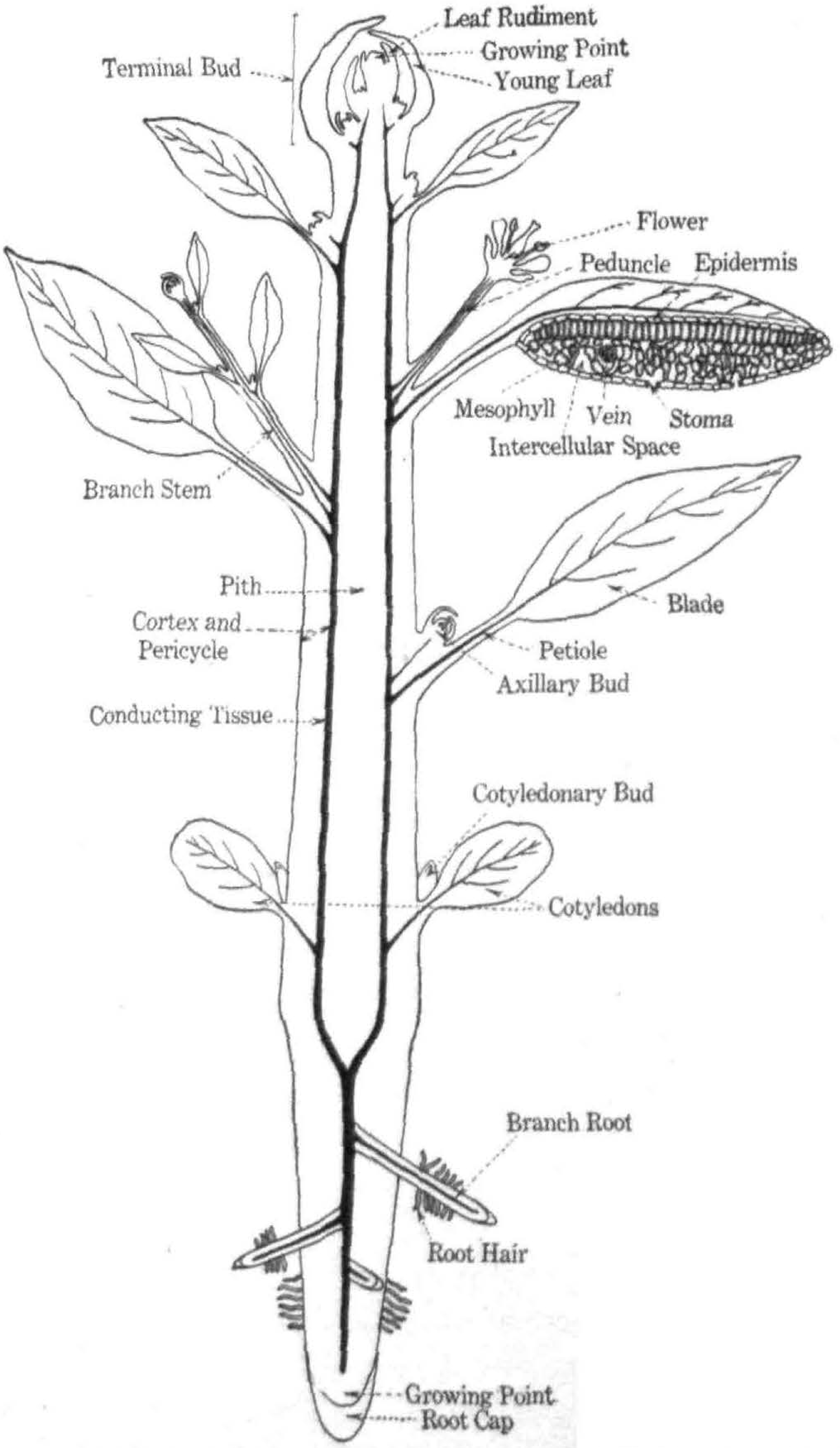


FIG. 1.—Principal parts of the seed plant body represented diagrammatically. (*After Holman and Robbins.*)

thus preserve the life of the race. However, we know that many seed plants, such as potatoes, asparagus, cane fruits, strawberries, and others may be propagated by using vegetative parts of the plants.

The above classification has a physiological basis.

We may also divide the seed plant body into two systems on a structural basis, as follows:

1. *Shoot system*, including stems, leaves, flowers, fruit and seed. The stems may be in the air (*aerial*) or *underground;* the leaves may be ordinary *foliage leaves*, *floral leaves* (flower parts), or *scale leaves*.

2. *Root system*, which may be in the *soil*, the *water* or *air*.

The roots, stems, leaves and flowers are not always typical, but may be modified or disguised, in some cases to such an extent as to be scarcely recognizable. For example, the tendril of the sweet pea is a leaf part, morphologically; the potato tuber, a modified stem; the sweet potato, a modified root.

Size and Form of the Seed Plant Body.—There is a remarkable variety of forms and sizes of seed plants in the world. The duckweeds are very small, simple seed plants floating upon the surface of ponds. They are without leaves or with only very simple ones, they bear one or more rootlets, and extremely small flowers which usually consist of a single stamen or a single pistil. At the other extreme are the Giant Sequoias of California; one individual, the General Sherman "big tree," measures 279.9 feet in height and 102.8 feet about the base.

We commonly make a distinction between *trees*, *shrubs* and *herbs*—plants which differ much in form and habit. Trees and shrubs are woody, while herbs possess less woody tissue and, consequently, are more soft and tender. The tree has a main trunk giving off branches at varying distances from the ground. The shrub may have a small main stem, but

the shoots that arise at its base are equal to it in size. We note differences in the shapes of plants. Contrast the apple tree with its oval shape with the cone shape of the pine or spruce. Observe the general columnar form of the corn plant, and note how different it is from the broadly oval form of a vigorous alfalfa clump. Again, we see that while most plants are erect, a number, like the strawberry and melons, are prostrate on the ground. Others, like the grape, are climbing, and gain mechanical support from other objects.

CHAPTER II

FUNDAMENTAL INTERNAL STRUCTURE OF PLANT BODY

Organs and Tissues.—We have said that the seed plant body is composed of a number of members: roots, stems, leaves, and flowers, bearing the fruit and seed. We may say that the plant body is composed of a number of *organs*, that is, well-defined parts that perform some definite function or functions. For example, those parts of the plant concerned with absorption we call *absorptive organs*, those that carry on reproduction, *reproductive organs*, and so on. The roots are the chief absorptive organs of all common seed plants, and the stamens and pistils of the flower the reproductive organs. Now, if we study microscopically the structure of organs, they are seen to be made up of one or more different groups of cells. Each distinct group of cells within the organ that has a common origin and a common rôle to perform, is designated a *tissue*. For example, the pistil (a reproductive organ of a flower) is composed of several different tissues such as parenchyma tissue, conductive tissue, and epidermal tissue. Still deeper analysis of tissues shows all to be made up of small microscopic units—the *cells*.

The Plant Cell.—*Discovery of the Cell.*—The discovery of the plant cell is attributed to Robert Hooke, an English lens manufacturer. In his microscopic study of thin sections of ordinary bottle cork, in 1667, he observed the cork tissue to be composed of very small compartments, very much alike in size and shape, and fitting closely together. It happens

that the separate units making up the cork tissue resemble the cells of a honeycomb, and hence Hooke gave the name "cell" to the units of cork tissue. Although an inappropriate name, in that the majority of plant cells have no resemblance to those of a honeycomb, the name still clings to botanical terminology. Hooke's discovery, although an epoch in the history of biology, was to be followed by others of far greater importance in that they tell us of the real nature of the cell, its marvelous inner structure, and most wonderful activities.

The Cell as a Unit of Structure.—Just as a brick house is made up of individual units, the bricks, so is a plant composed of individual units, the *cells*. *A plant is made up of cells and the products of cells, and nothing else.* The wood, the root, the flower parts, the leaf, are made up of cells and cell products. This must not be understood to mean that all parts of a plant are alive; but the non-living portions are products of the living material within the cell.

The Cell as a Unit of Plant Activity.—The activities of a plant take place within the cells, for it is within them that we find the living material—protoplasm. Some of the simplest plants are *unicellular*, that is, one-celled. In such a case, the individual plant is simply one cell. That one cell, that individual, is capable of carrying on all the processes—absorption, respiration, digestion, assimilation, reproduction, etc.—upon which its life and the life of the race to which that plant belongs are dependent. Somewhat higher in the scale of plant life, we find some plants, algæ, for example, composed of a number of cells, several hundred, for instance. In this case, the individual plant is *multicellular*, and yet, in this plant, each cell is a unit of activity, and each carries on its activities quite independently of the others to which it is united, as is evidenced by the ability of the individual cells to live and reproduce when separated from its neighbors. In the higher seed plants, there are many different sorts of cells,

both as to structure and function, and the different cells are more dependent one upon another than are the cells that make up the simple algal filament. Yet, even in the seed plant, each cell is a unit of activity, and each is carrying on

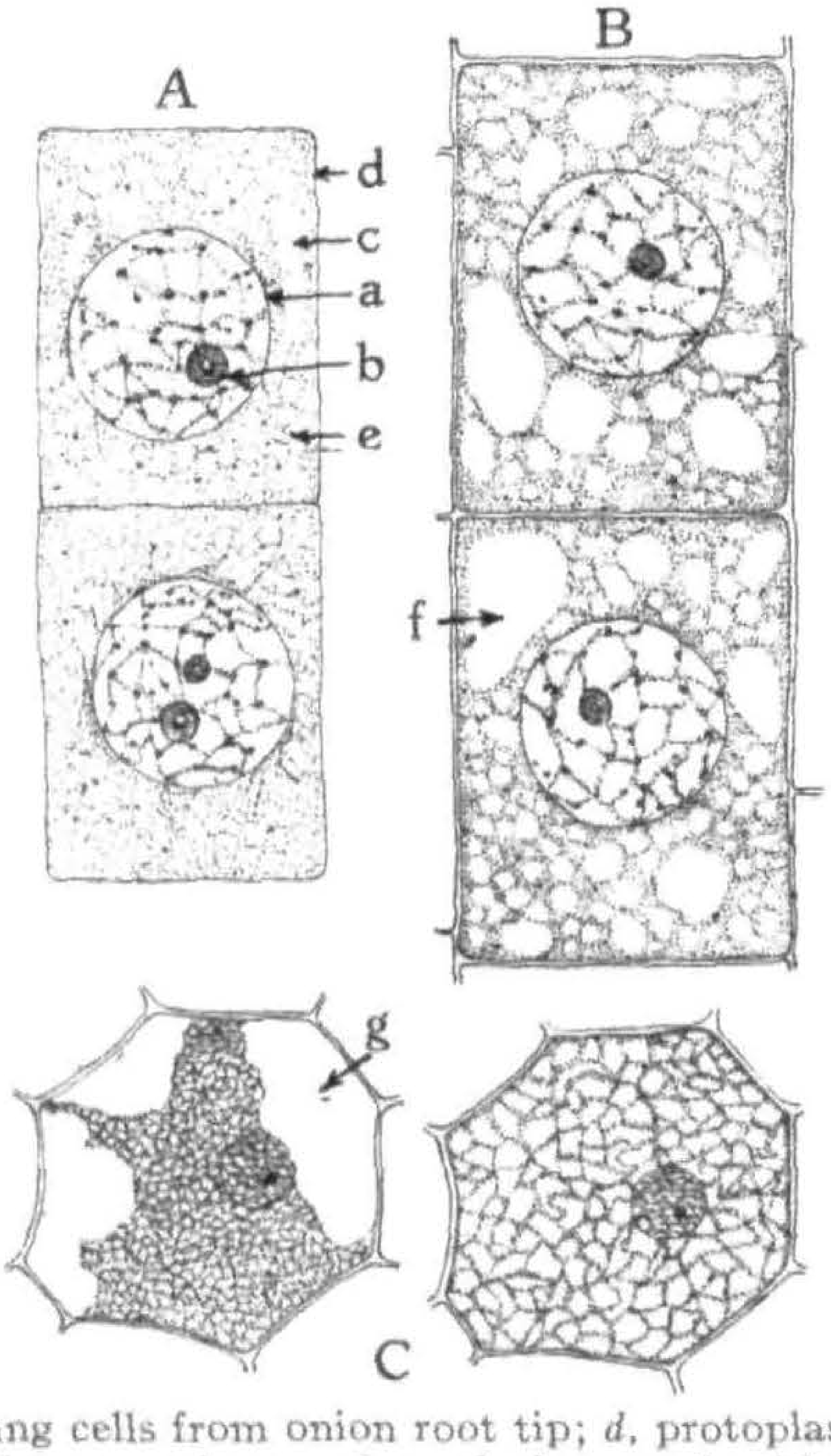


FIG. 2.—*A*, young cells from onion root tip; *d*, protoplasmic membrane; *c*, cytoplasm; *a*, nuclear membrane; *d*, nucleolus; *e*, plastids (black dots). *B*, older cells farther back from the root tip; *f*, vacuole; note that the cells have enlarged. *C*, epidermal cell of Tradescantia zebrina; in its natural condition of the right, and, on the left with the protoplast drawn from the cell wall as the result of immersing the cell in a solution the concentration of which is greater than that of the cell sap. This phenomenon is called plasmolysis. *g*, contains the plasmolyzing solution. (*After Stevens.*)

its functions more or less independently of its neighbors. The *physiological unit of the plant is the cell.*

The Structure of the Plant Cell (Fig. 2).—It must be understood at the beginning that plant cells vary a good deal in size and shape. However, the fundamental structure of

all plant cells is much the same. The plant cell consists of a living mass (*protoplast*) of protoplasm enclosed in a non-living *cell wall*. The wall is manufactured by the protoplast, and serves as a protection to it. If we examine the *protoplast*, we see that it is composed of rather definite parts. There is an outer, thin, and transparent living membrane about the protoplast, which is only made manifest by treating the cell in a special manner. This membrane is known as the *protoplasmic membrane*, *ectoplasm* or *hyaloplasm*. It is of importance in the intake and outgo of substances. If a plant tissue is immersed in a sugar or salt solution which has a greater concentration than the cell sap, water is drawn from the protoplast of each cell through the protoplasmic membrane, and the protoplast shrinks, thus pulling the membrane away from the cell wall and making it visible microscopically. Imbedded within the body of the protoplast there is a darker and denser mass of protoplasm, the *nucleus* surrounded by its own living nuclear membrane. It may contain one to several small, darker bodies, the *nucleoli*. The protoplasm outside the nucleus is designated the *cytoplasm*. Hence we see that the protoplast is made up of three main parts: *protoplasmic membrane*, *cytoplasm and nucleus*. The protoplasm has spaces within it, which are filled with *cell sap*. These spaces are called *vacuoles*. However, one must not think of the cell-sap spaces in the protoplasm as vacuums, as the rather inappropriate name "vacuole" may suggest. Vacuoles are numerous and small in the young cells, but as the cell ages, they coalesce to form larger spaces. In old cells, there is one large central vacuole, while the cytoplasm and nucleus are squeezed out close to the cell wall. All vacuoles are bordered by a protoplasmic membrane, similar to the ectoplasm.

Suspended within the cytoplasm are specialized living bodies, the *plastids*, also numerous *granules*, which may be of

living material and of insoluble food particles, such as starch or protein. The cytoplasm may hold insoluble crystals of salts, chiefly calcium oxalate. Let us arrange the parts of cell thus far described in outline form as follows:

- Plant cell
  - Cell wall (non-living)
  - Protoplast
    - Protoplasmic membrane (living)
    - Nucleus (living), containing one or more nucleoli
    - Cytoplasm
      - plastids (living)
      - granules (living or non-living)
      - crystals (non-living)
      - vacuoles, containing cell sap.

The Cell Wall.—The cell wall is a product of the protoplast. When young it is almost pure cellulose. As the cell grows older, its wall may thicken and become denser, and have added to it certain substances such as lignin, suberin, cutin and pectin which give it different physical and chemical qualities.

Plastids.—These are specialized masses of protoplasm suspended within the cytoplasm. They vary in size and form. There are three sorts of plastids distinguished by their color: (1) *leucoplastids*, colorless; (2) *chloroplastids*, green; and (3) *chromoplastids*, yellow, orange or red.

Nucleus.—All typical cells have a definite nucleus. It is wrong to regard the nucleus as the "seat of life" of the cell, for other portions of the cell are important, but it is a most essential part of the cell. If the nucleus is separated from the cytoplasm by artificial means, the cell dies. Its presence is needed, it seems, to stimulate respiratory activity. Moreover, reproduction of the cell—its division to form two cells—involves definite nuclear changes; a knowledge of these has led to the opinion that the determiners of hereditary characters are carried by a special portion (chromatin) of the nuclear matter. The structure of the nucleus is indeed complex, and there is a wonderful chain of changes that it goes through at the time of cell division.

Protoplasm.—In 1840, Hugo von Mohl drew attention to the fact that the slimy substance in the plant cell was responsible for its life, and that as soon as it was removed, the cell no longer had the properties of livingness. The name *protoplasm* was applied to the living portion of the plant cell. Somewhat later, 1850, Ferdinand Cohn, gave positive evidence of the identity of the living material (protoplasm) in plant cells, and of the living material (so-called "sarcode") in animal cells.

If we examine a small bit of protoplasm under the microscope we see that it is a semi-transparent, jelly-like, rather granular substance, resembling very much the white of an egg, and that it feels slimy.

Protoplasm is a very complex chemical substance. Although no element has ever been found in protoplasm that is not also found in the common substances in the world about us, the exact arrangement and proportions of these elements has not been ascertained, except in a general way. It is quite clearly established that protoplasm is a protein, of complex nature, with water as a solvent. Proteins form about one-half or two-thirds of the dry substance of protoplasm. The remainder is fat, sugar, and other carbohydrates, organic acids, organic bases, and some mineral substances.

CHAPTER III

ROOTS

Development of Root Systems.—The *root system* of a plant is the entire collection of roots. Let us trace out the development of different root systems, starting with the seed. If we examine soaked grains of wheat, or bean seeds, or beet seeds, we observe that there is a young root already formed within the seed. Three germinating stages in wheat are shown in Fig. 3. The one principal root or *primary root* we see in the grain is the first to appear. It breaks through the root sheath (coleorhiza) which remains as a collar about the root where it ruptures the grain coat. Very soon two pairs of lateral roots appear which may be followed, in some instances, by other primary roots. The first roots which make their appearance constitute the *primary root system* or *temporary root system.* Since these roots were in the seed in the embryonic condition they are called *seminal* (seed) roots. The secondary roots appear in whorls at the joints on the stems some distance above the temporary roots. The first whorl of permanent roots in wheat is generally about 1 inch below the soil surface, no matter at what depth the grain was planted (Fig. 4). One whorl of roots after another is formed above the first one, and as a result there is built up a fine network of roots, with their branches. A root system such as described in wheat is called a *fibrous root system.*

Roots not arising from the seed or as branches of seed roots, but from stems or leaves, are called *adventitious roots.* Hence

the *fibrous root system* of wheat, and of all the other cer and grasses, is in reality composed of roots that devel *adventitiously*. Adventitious root systems may appear under a variety of conditions. When young onion "sets" are placed in the ground, a set of roots (adventitious roots)

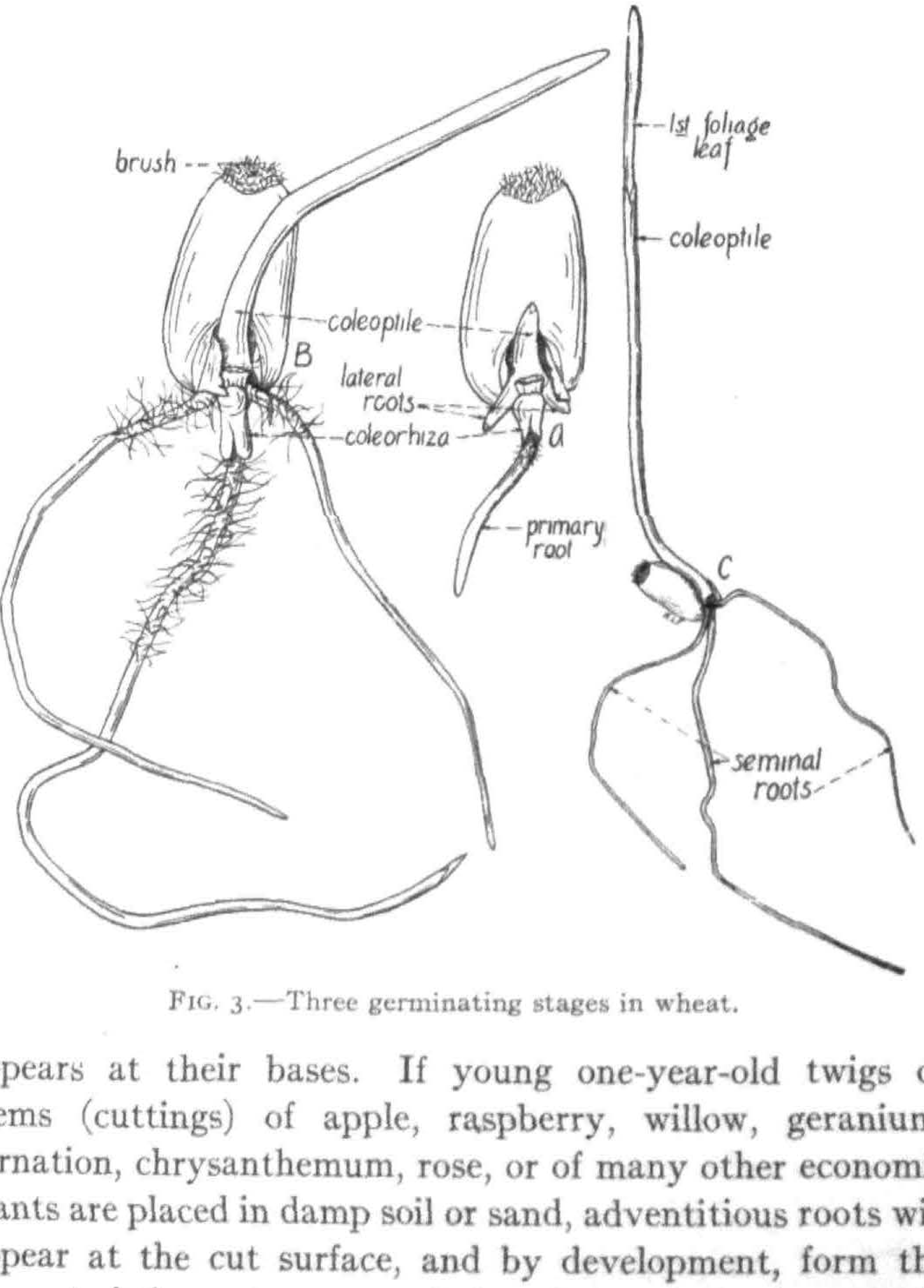


FIG. 3.—Three germinating stages in wheat.

appears at their bases. If young one-year-old twigs or stems (cuttings) of apple, raspberry, willow, geranium, carnation, chrysanthemum, rose, or of many other economic plants are placed in damp soil or sand, adventitious roots will appear at the cut surface, and by development, form the characteristic root system of the plant. Some leaves will

even develop adventitious roots from cut or wounded leaf veins. This is true of such leaves as begonia, gloxinias, and

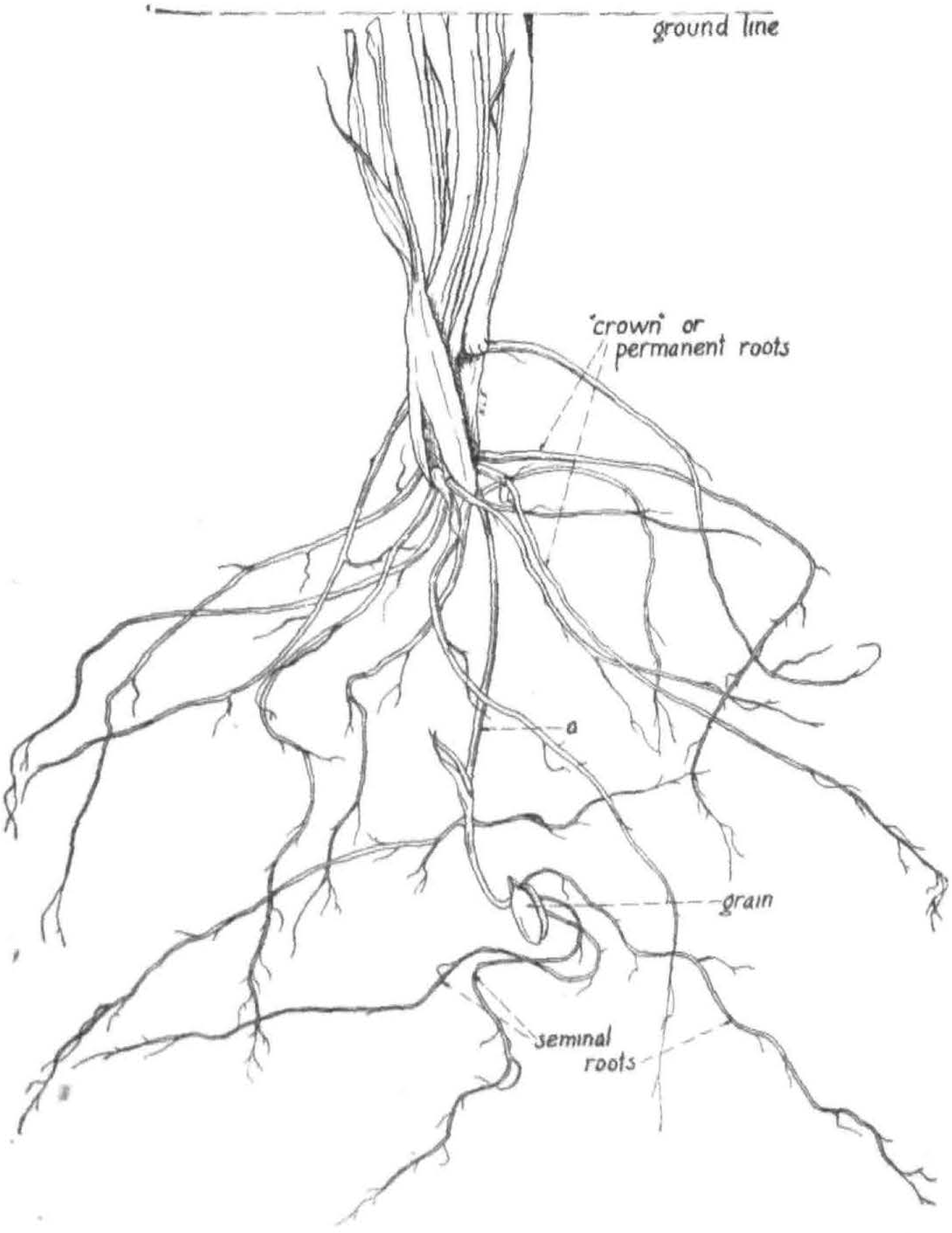


FIG. 4.—In spite of the fact that the grain of wheat was planted at too great a depth, the permanent roots were formed at about 1 inch below the soil surface.

bryophyllum. In the black-cap raspberry and in dewberries, a shoot (stem) may bend over by its own weight, and where it strikes the ground, develop adventitious roots, and thus

secure a foothold. When once the tip has rooted well, the stem may be cut loose from the parent stem and such rooted tips used as "sets." Strawberries produce slender stems, called *runners*. Adventitious roots may be produced at the nodes.

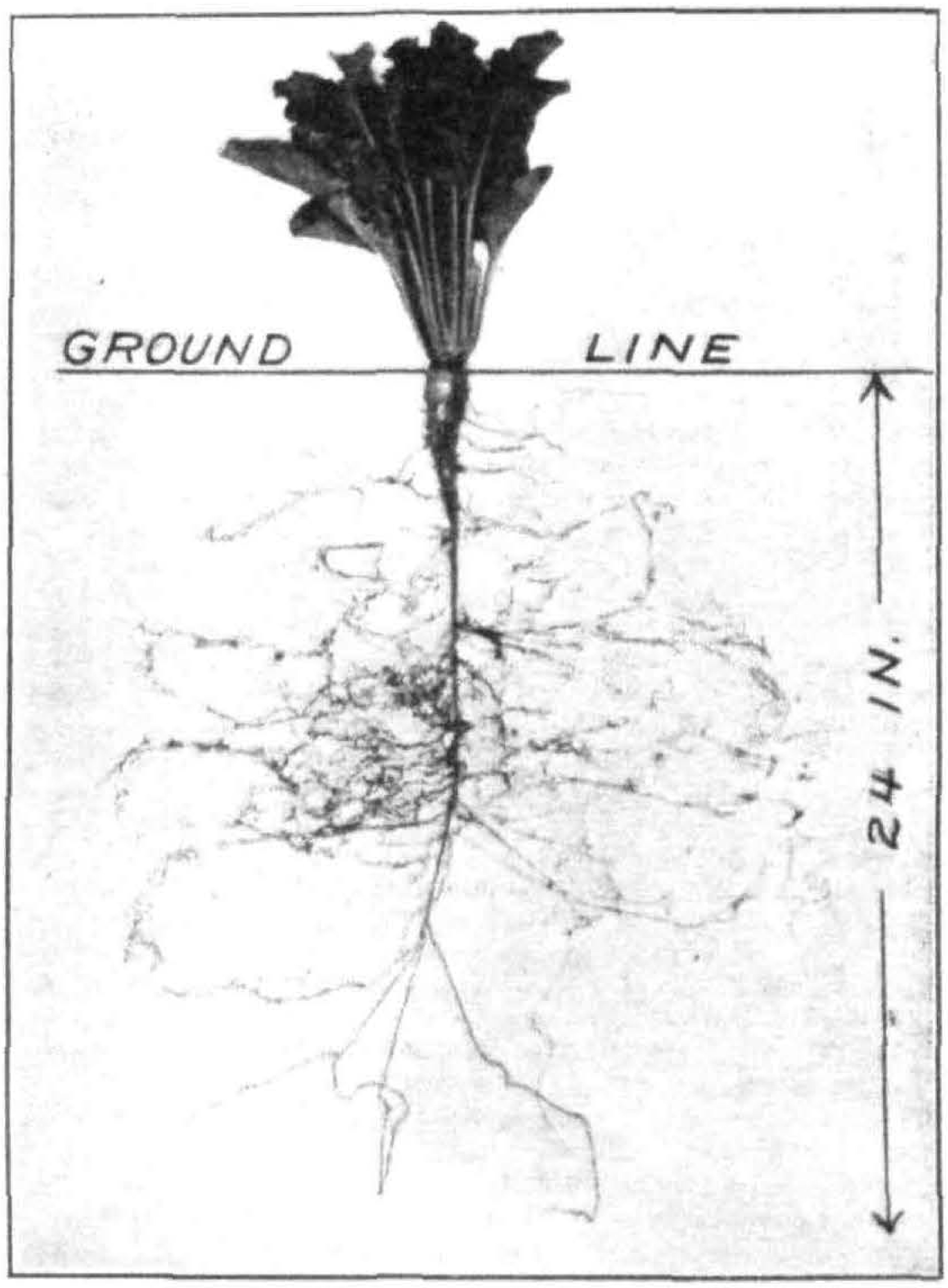


FIG. 5.—Tap-root system of young sugar beet. (*Maxson.*)

A very different sort of root system develops in such plants as the beet, radish, turnip, parsnip and carrot. In the germination of the beet seed, for example, the primary root pushes out, takes a straight downward course, and gives off a few lateral roots. The primary root system of the beet consists

of one main root extending downward, with a few fine laterals. Adventitious roots do not arise, as in wheat, nor does the primary root system die, as it does in wheat, but the main *tap root* of the young plant continues to elongate, and to give off lateral roots and rootlets (Fig. 5). The "beet" itself is for the most part an enlarged tap root. The tap root of the sugar beet may reach a depth of 4 feet, and often 6 or 7 feet. The upper laterals are the largest of the branch roots and extend farthest in the soil, spreading almost horizontally 2 to 3 feet. The lower laterals are more vertical and those near the very tip are almost parallel with the tap root. A root system such as possessed by the beet, radish, turnip, parsnip, carrot, dandelion, red clover, and many other plants is called a *tap-root system.*

The Work of Roots.—A root system *absorbs*, *anchors*, and serves as a *storage organ.* The small, young, tender roots, with their root hairs, are largely absorption roots, but as the plant gets older, new absorptive roots are continually being formed, while the older roots become thick and woody and serve mainly as anchorage organs. Familiar storage roots are those of the beet, carrot, turnip, parsnip, sweet potato, and dandelion. The foot material stored up by such plants for their own use furnishes a large proportion of the food supply of man. Irish potatoes (tubers) are not roots, but stems, and hence their discussion will be reserved for the proper section in the book.

Effect of Environment upon Character of Root System. It is noted, when roots make a vigorous growth, as they will under favorable soil conditions, that there is a very extensive system of rootlets developed. Corn is found to have a large part of its lateral root system in the surface layers when the soil is poor. The general form of a root system may be changed by transplanting. As a result of the necessary injury accompanying this process, there is developed a compact

root system. Desert plants usually have an extensive root system, reaching to considerable depths. Swamp plants, even trees, develop a spreading, and comparatively shallow root system. The method and amount of watering affect the general shape of the root system. Fruit trees, for example, send their roots into the deeper soil layers if the surface layers are dry, but if the ground water level is close to the soil surface the root system will be more superficial. The character of the root system is often an index of soil conditions.

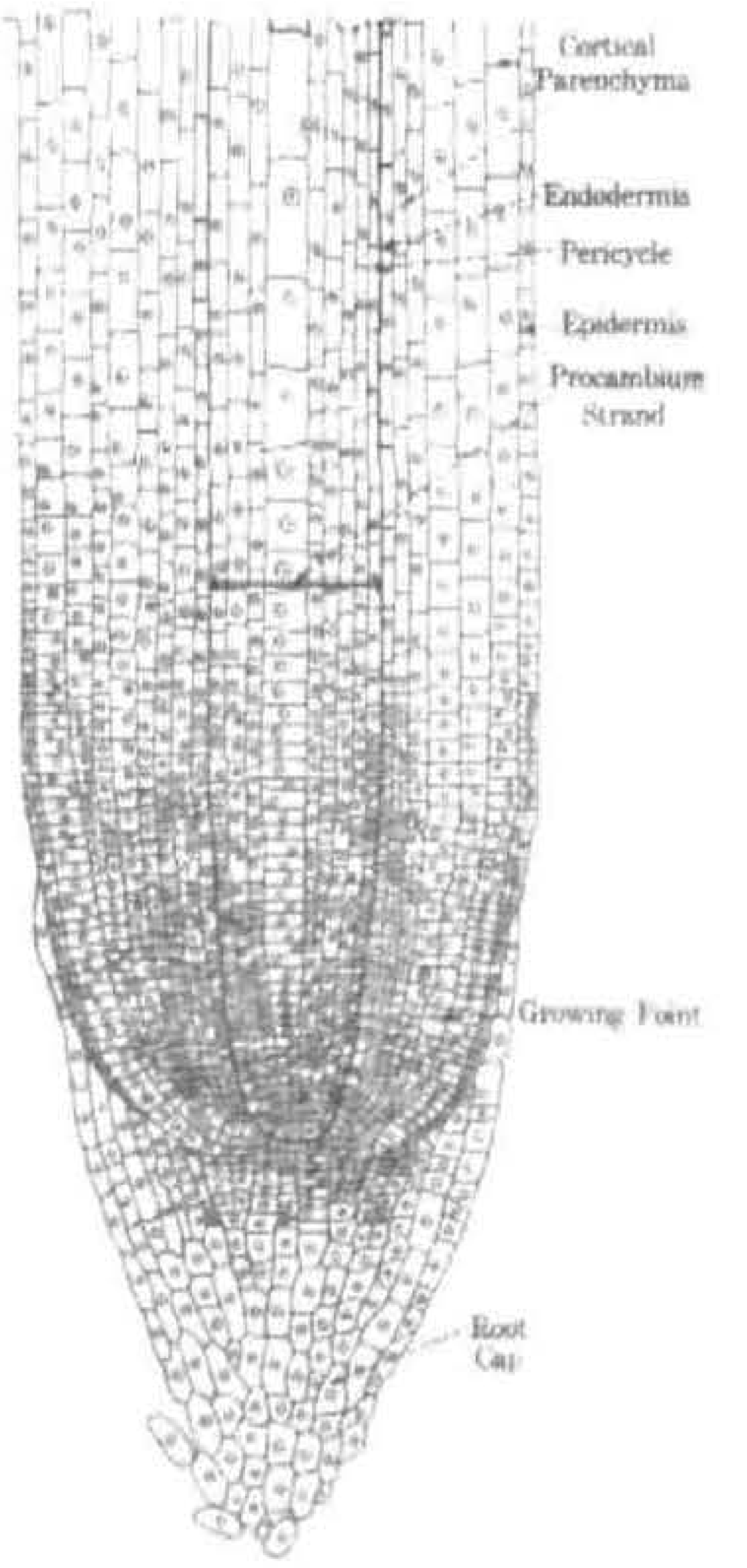


FIG. 6.—Median lengthwise section of the apex of a root of barley. (*After Holman and Robbins.*)

General Characteristics of Roots.—It will be recalled that the seed plant body possesses a number of members, each with more or less distinctive characters. Roots have characteristics which stand out in quite marked contrast to those of other plant members. Roots do not give off their branches in a regular order, as stems do. They do not bear buds, except in very rare cases. Roots usually bear a root cap (Fig. 6) which protects the growing point, while the growing point in stems is either naked or surrounded by modified leaves (bud scales). There are other characters which will be mentioned further on.

Classification of Roots Based upon Their Medium of Growth.—The medium of growth of most roots is soil. Such roots may be called *soil roots*. It is customary for us to think of the root system of a plant as growing in the soil, just as we associate the shoot system with the air above

ground. However, not all roots live in the soil, and not all shoots live in the air. There are *water roots*, and *air roots*, as well as the ordinary sort, *soil roots*. Water roots occur in such floating plants as the duckweeds, and water hyacinth (*Eichhornia speciosa*). Water roots produce but a few branches. They possess no root hairs; absorption takes place through any cells on the surface. Air roots occur in many plants, such as corn, Virginia creeper, tropical orchids, the banyan and other species of *Ficus*. In addition to the ordinary underground (soil) roots, corn develops aerial (air) roots, the so-called *prop* or *brace roots*. These arise at successive levels above the surface, extending obliquely downward. As aerial roots, they are unbranched, but they branch profusely when they strike the soil. They have the rôle of absorption, then, as well as anchorage. In the banyan, for example, the air roots are often very large, and arise from branches far above the ground. They grow downward, and when they strike the ground, become firmly attached, and act as a support or prop to the heavy branches.

Structure of Roots.—Let us cut a median (middle) lengthwise section of a young root. It will appear as in Fig. 6. We shall see then that the root has a cap of loose cells at the tip. This protective structure is called the *root cap*. Just back of the root cap is the region of greatest cell multiplication (Fig. 6), composed of cells that are actively growing. The very tip of the cap is continually sloughing off, while new cells are being added to it just in front of the growing point.

The actively growing cells which constitute the growing point form a tissue known as *primordial* meristem. From this tissue, three primary meristems are differentiated, namely (1) the *protoderm*, (2) the *ground meristem*, (3) and the *procambium*, a single central strand. These by further differ-

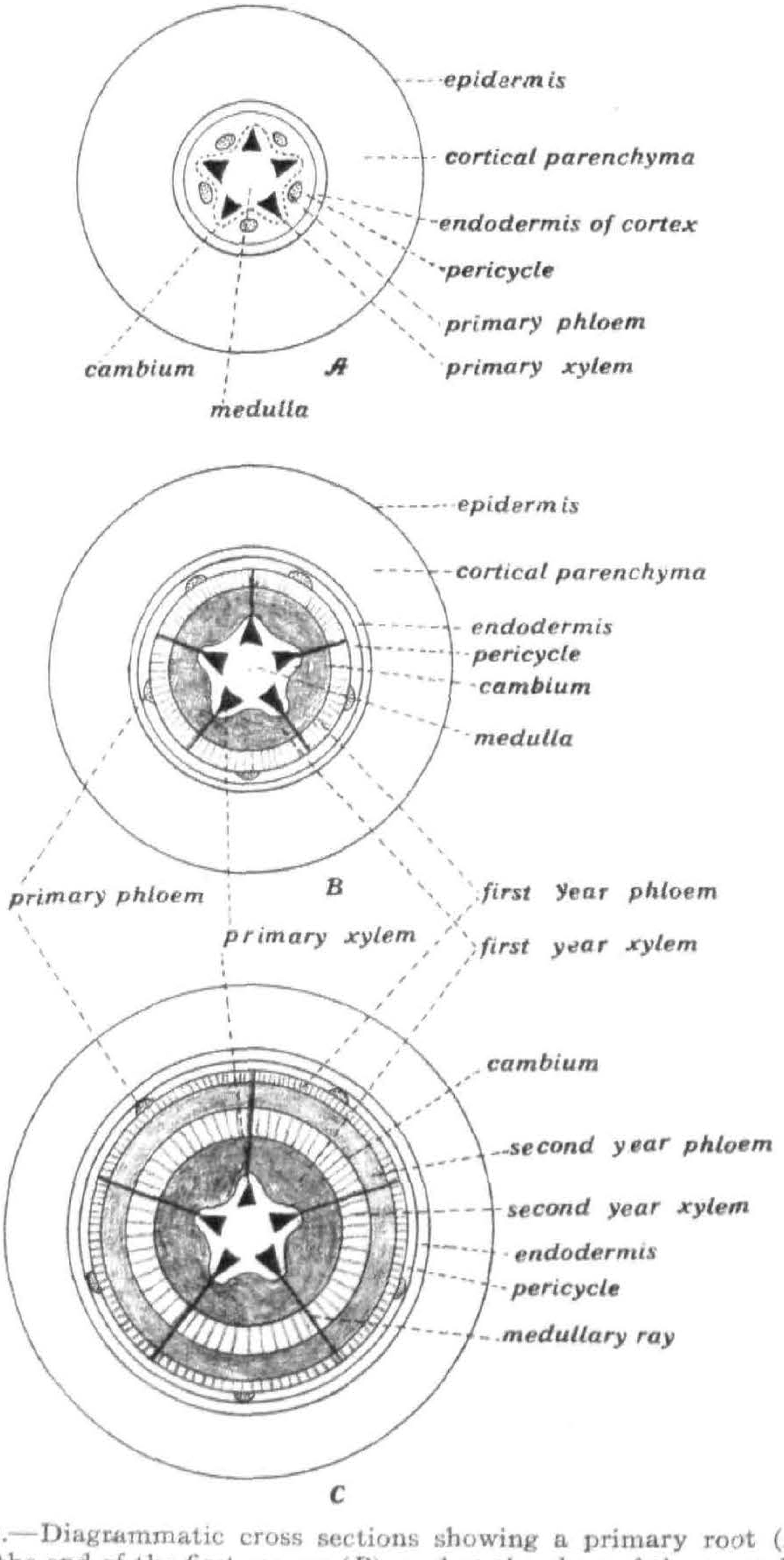


FIG. 7.—Diagrammatic cross sections showing a primary root (*A*), the same at the end of the first season (*B*), and at the close of the second season (*C*). (*After Coupin.*)

entiation give rise to the following tissues which may be seen to advantage in a cross section through a mature part of the young root: (1) *Epidermis* (from protoderm); (2) *cortex* (from ground meristem); (3) *pericycle* (from ground meristem); (4) *vascular cylinder* (from the procambium strand). It is often possible to strip the cortex and epidermis from the vascular cylinder, which is composed of tough, fibrous tissue.

The *cortex* (Fig. 7) is composed of large, thin-walled cells, which do not fit closely together, but leave air spaces (intercellular spaces) between. The innermost cortex layer is called the *endodermis*. The epidermal cells may become prolonged to the side to form *root hairs*. The *central cylinder* (Fig. 6) is bounded by a single layer of cells, the *pericycle*, which lies adjacent to the endodermis. Within this cylinder are found alternating *bundles* or *strands*. The woody, water-conducting bundles are called the *xylem*, the softer, food-conducting bundles, *phloem*. The central portion of the cylinder is composed of large, loosely fitting cells, making up the *pith* or *medulla*.

Side roots arise from the pericycle, and push their way through the cortex and epidermis (Fig. 8). This method of origin of side branches is characteristic of roots.

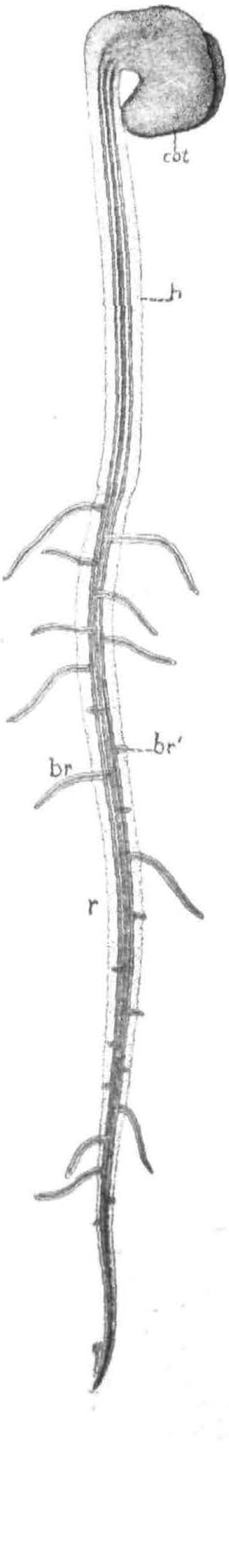


FIG. 8.—Young root of white lupine showing origin of lateral roots from the stele. (*After Gager*.)

In stems the side branches are of epidermal origin (Fig. 15). Branch roots are said to have an *endogenous origin*, while branch shoots (except those in monocots) have an *exogenous* origin.

As the root grows older, new xylem and phloem are formed, and by and by, it becomes very tough and woody, serving as an efficient anchorage organ.

FIG. 9.—Wheat seedling showing soil particles clinging to root hairs; note that the root cap is free of root hairs.

Root Hairs—the Absorbing Organs of a Plant.—A problem of all our common plants is to take in as much water from the soil as they lose to the air, *i.e.*, to maintain a balance between water intake and water outgo. We speak of the roots as the absorbing organs of the plant. In a sense this is true, but it must be understood that water and soil solutions are not taken in at all points on the surface of the root system. Practically all absorbed substances enter the plant through root hairs, which are found near the tips of the smallest rootlets. In reality, the root hairs are the absorbing organs of a plant. When we pull up any common herbaceous plant, we observe, as a rule, a large number of hair-like rootlets as branches of larger roots. These fine "hair roots" are sometimes mistaken for root hairs. But, closer examination, in which a hand lens may be necessary, shows us that these hair roots are the bearers of root hairs. In fact, root hairs are found only on the smallest and youngest rootlets.

Root-hair Zone.—Root hairs do not grow along the full length of a rootlet, but occupy a definite zone, designated the *root-hair zone*. This is clearly seen in young seedlings,

grown on moist filter paper. The root-hair zone appears as a white fuzzy coating. The root cap is free of root hairs. The length of the zone varies from a few millimeters to several centimeters. The root-hair zone of seedlings grown in soil is plainly evident from the mass of soil particles held by the root hairs (Fig. 9). Each root hair in its growth flattens out over, and sometimes partially surrounds, the soil particles with which it comes into contact, thereby forming a close connection with the water and solutes that form a thin film around each soil particle. Furthermore, the root hairs become mucilaginous, and this, along with their partial

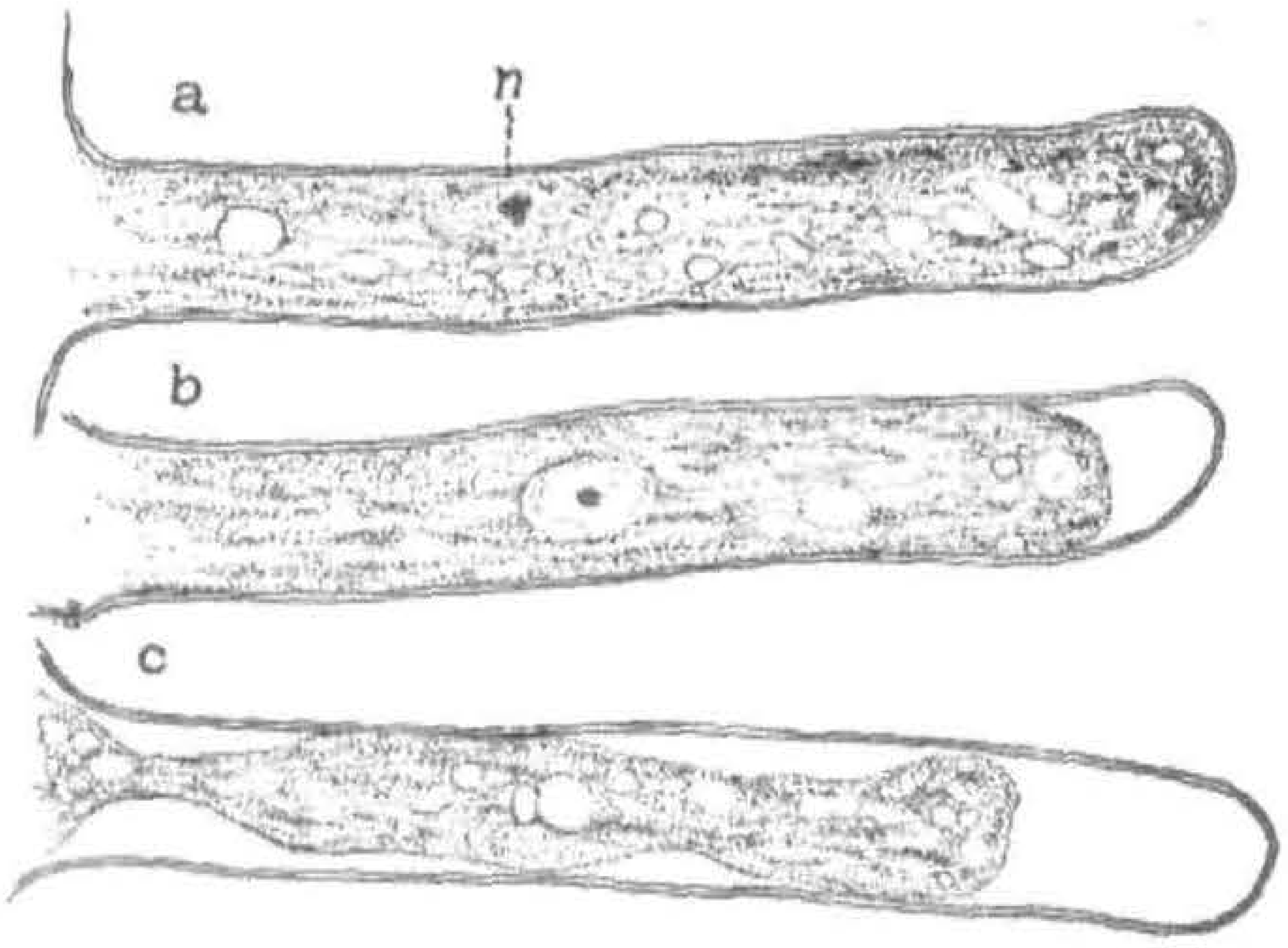


FIG. 10.—Root hairs. *(After Gager.)*

surrounding of particles, explains the presence of the mass of soil particles that clings to rootlets in the root-hair zone. Root hairs are short-lived, persisting for only a few days or weeks. New hairs are constantly formed anew at the anterior end of the root-hair zone, while those at the posterior end are dying. Root hairs do not become roots.

Structure of a Root Hair.—The root hair is a simple, lateral prolongation of an epidermal cell (Fig. 10). It has the shape of a slender tube which may, however, become greatly contorted in its growth between and about soil particles. Root hairs vary in length from a fraction of a millimeter to 7 or 8 millimeters. The walls are thin and of almost pure

cellulose. A thin layer of protoplasm may line the walls, and the nucleus usually occupies a position near the apex. The central vacuole is large, and is filled with cell sap. The cell sap contains water, and various organic and inorganic substances in solution.

Effect of External Factors upon Development of Root Hairs.—Most air and water roots have no root hairs. Soil roots, such as those of conifers, oaks, and others that are surrounded by a fungus (mycorrhizal growth) possess no root hairs. In the case of ordinary soil roots, root-hair development is usually meager in very wet soil. Corn roots develop root hairs in abundance in moist air, but none at all in water. The absence of root hairs in very wet soil, and in water, is probably to be attributed to poor oxygen supply. In a water-soaked soil, the air spaces are filled with water. Our ordinary crop plants require a well-aired soil in order to develop root hairs in abundance. One of the chief objects of stirring the soil is to admit air to the roots. Orchard trees have been known to die as a result of the "puddling" of the soil. Trees are also sometimes killed by cattle tramping and packing the ground about them, such that the air supply to the roots is largely cut off. Root-hair development is often inhibited by a concentrated soil solution. High temperatures, and low temperatures, are inimical to root-hair growth. Root hairs develop in the light and dark about equally well, providing there is ample moisture.

Length of Life of Roots.—Roots that live but one vegetative period, that is, one season, are *annual*. All of our common cereals, such as wheat, oats, barley, rye, corn, rice, sorghum, and also such common crop plants as buckwheat, beans, peas, tomatoes, melons, etc., have annual roots. *Biennial* plants live two vegetative periods. Common biennials are beet, cabbage, carrot, and parsnip. From the seed of beet, for example, there is developed the first season

a large fleshy tap root, and a short crown from which the leaves arise. This fleshy structure ("beet"), stored with food, rests over the winter, and the next growing period sends up stout, branching stems to a height of 3 or 4 feet, which give rise to flowers and seed (Fig. 124). At the end of the second season of growth, after seed production, the entire plant dies. Under our cultural conditions winter wheat is a biennial. The roots of trees and shrubs and some herbs live from year to year, increasing in size each season. Such plants are *perennial* in habit. In most cases the length of life of roots is the same as that of the shoot system. However, underground perennial stems, such as are possessed by quackgrass, Canada thistle, false Solomon's seal, etc., may have annual roots.

COIMBATORE

CHAPTER IV

STEMS

Development of Shoot System.—When a grain of wheat germinates, the primary root is the first to appear. Very soon lateral roots make their appearance, forming a primary root system. Also, the young stem (Fig. 3) elongates, and there is formed the first shoot system of the plant. Elongation of the stem continues by growth at the tip, where the cells are young and active.

It is observed that the stem is divided into sections (internodes) (Fig. 26). The *nodes*, the enlarged joints between the internodes, give rise to leaves. If we follow the wheat plant through its life, we observe that the stem terminates in an inflorescence (flower cluster). Now, in addition to the one main stem that arises as a prolongation of the embryonic stem in the seed, branches arise from the lower nodes. These branches arise in the axils of the lowermost leaves, in most cereals. In cereals, this branching is known as "*stooling*" or "*tillering*." Common cereals invariably produce a number of tillers or branches from the primary stem, and these in turn other tillers(lateral branches), so that under favorable conditions several dozen culms may result from a single seed. In the wheat plant, two or three weeks old, three or four buds (young stems) may be found, one in the axil of each leaf. Tillering results from the outgrowth of these lateral buds. Hence, as a result of the elongation of the main growing point, and of the lateral growing points into lateral branches of the primary stem, there is built up a shoot system, with its leaves and flowers.

Buds.—A bud is an undeveloped stem; it is simply a young shoot. In an ordinary shoot, an apple or peach twig for example, the internodes are considerably elongated. In rapidly growing water sprouts, internodes may be several inches in length. A bud is a very short, young shoot in which the internodes are few or are exceedingly short. That a bud is a young, individual shoot in itself is shown by the fact that buds may be removed from a branch and applied to the surface of the growing tissue (cambium) of another branch (stock) and successfully grown there. In fact, bud grafting is a common horticultural practice. The tip of the bud is usually protected by a series of overlapping scales (bud scales), which are in reality modified leaves. Naked buds are not protected by scales; they are found on woody plants of the moist tropics, and are the only sort on herbaceous plants the world over.

Classification of Buds.—Buds may be classified as to development into: (*a*) *leaf*, (*b*) *flower*, and (*c*) *mixed buds*. If we open up a *leaf bud*, we find a very much shortened axis or stem bearing a number of small leaves. As the leaf bud is a young shoot, it may as properly be called a *branch bud*. That is, it elongates into a branch which bears leaves. The new shoot, just as the old one from which it came, ends in a bud, and in the leaf axils other buds arise. If we open up a *flower bud*, we find one or more young flowers. In plums, for example, the number of flowers in a bud varies from one to five, two and three being the most common numbers (Fig. 170). *Mixed buds* contain both flowers and leaves. The terminal buds at the ends of the short "spurs" in the apple are mixed buds (Fig. 157).

It is not always possible to distinguish leaf from flower buds by their external appearance. In some cases, however, they have a different shape. In the apple, for example, fruit buds (here, really mixed buds) are rather thick and

rounded, while leaf buds are smaller and more pointed. In all plums, the flower buds are lateral, and usually stand out at an angle of about 30°, while leaf buds are more appressed to the stem.

Buds may be classified as to their *position on the stem* into: (*a*) *terminal*, (*b*) *lateral or axillary*, (*c*) *accessory or supernumerary*, (*d*) *adventitious*, and (*e*) *dormant*.

Most stems end in a bud which is known as a *terminal bud*. It is almost always a leaf bud; occasionally it bears flowers, too, as in the apple. The terminal bud is normally the most vigorous of all on the stem, as is evidenced by the fact that it usually elongates into a shoot which exceeds in length those from the lateral buds. *Lateral* (side) *buds* arise in the leaf axils. They give rise to side branches or to flowers. *Accessory* or *supernumerary buds* are extra ones coming out in the leaf axils. They are best shown in the maples and box elder. *Adventitious buds* arise out of order, in unusual places, not always in leaf axils or at the end of a stem. They are often stimulated by injury. For example, when a branch is cut back, numerous adventitious buds develop about the edge of the cut surface. *Dormant buds* are ones that have arisen in a regular fashion in the leaf axil, but which, for some reason, do not develop. Hence, they may be grown over with the succeeding layers of wood and lie buried within the tissue in a latent condition. Such a bud may be called into activity later in the life of the plant and come to the surface. It would appear to be *endogenous* in its origin, while in reality it is *exogenous*. Irregular branching may result from the development of dormant buds, or as is more commonly the case, from the development of adventitious buds.

Buds may be classified as to their *arrangement on the stem* into: (*a*) *alternate*, (*b*) *opposite* and (*c*) *whorled*. It is well to keep in mind that bud arrangement is the same as leaf arrangement, for the reason that buds normally develop in

each leaf axil. Furthermore, as leaf buds develop into shoots, the method of branching, and hence the form of the plant, is largely determined by the bud arrangement.

When one bud occurs at each node, they are said to be *alternate* (Fig. 11). When two buds stand at a node, they are *opposite* (Fig. 109). When more than two buds stand at a node they are said to be *whorled*.

Bud Variation.—This is a more or less common occurrence in trees of all varieties. The buds on an apple, peach, or citrus tree, for example, differ from each other in important respects. That this difference really exists can be well shown by removing branches or buds and growing them into independent plants. If we do this we will find that the individuals from the separate buds may vary in such respects as habit of growth, manner of branch-

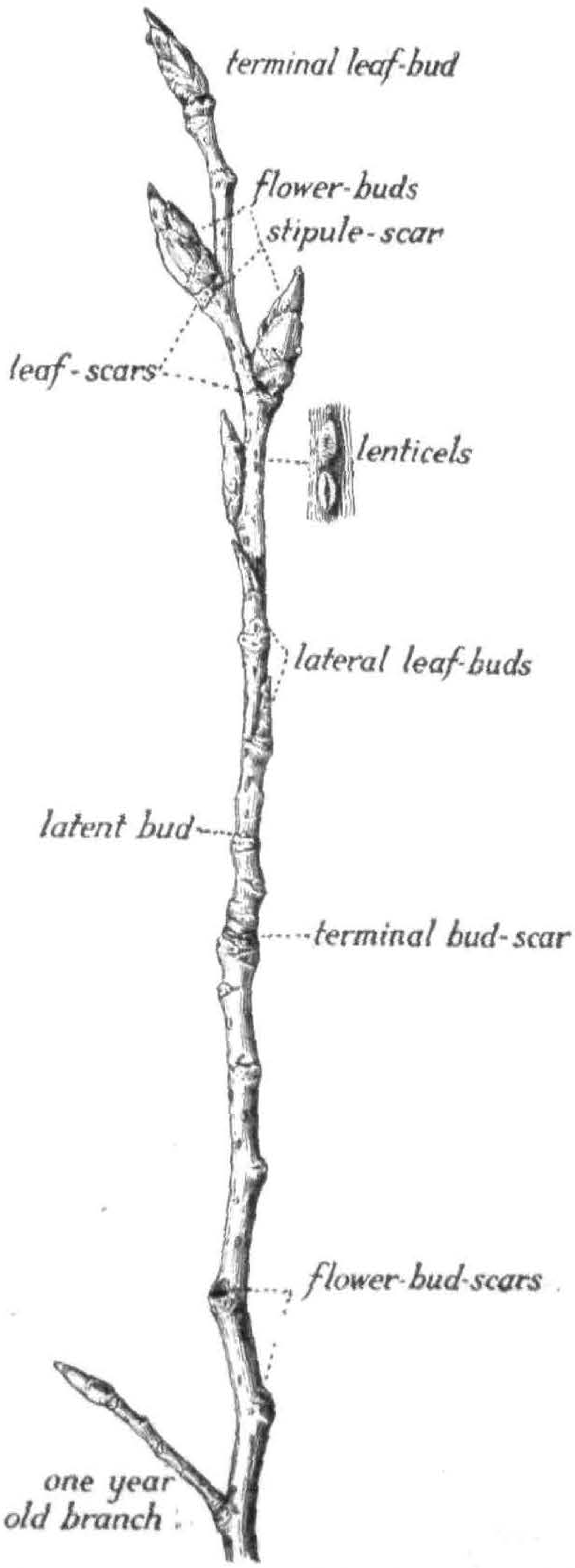


FIG. 11.—Cottonwood twig two years old. (*After Longyear.*)

ing, nature of foliage, form, color, texture and yield of fruits.

Nearly all our fruits are multiplied by bud propagation (asexual parts) and not by seed (sexual parts); and many of the varieties of fruits now in cultivation are in reality bud varieties or "sports." A certain branch on a tree is observed to differ from the rest in some marked respect; and this branch is taken off and propagated as a new variety.

General Characteristics of Stems.—Let us now examine a winter twig of the cottonwood, for example, that is several years old, such as pictured in Fig. 11. At the tip is a large *terminal bud.* If it is broken open, young overlapping leaves are found within. It develops into a leafy branch. The growth in length of the shoot results from the lengthening of the internodes in the bud. Along the side of the stem are *lateral* buds at regular intervals. These may be leaf buds or flower buds, as can be positively determined by breaking them open. Below each bud there is a half-moon-shaped *leaf scar.* By examining the leaf scar with a hand lens one sees several small *bundle scars* on the surface. Bundle scars are left by the vascular bundles that pass from the woody stem into the petiole (stem) of the leaf. *Inflorescence scars* are large circular or oval scars left by the falling off of flower clusters. A leaf scar is observed beneath each inflorescence scar. The twig growth of each year is clearly distinguished by a ring of scars. When the closely arranged bud scales of a terminal bud fall off in the spring they leave a number of scars so close together as to make a *ring.* Hence the limits of two successive years' growth are marked by bud scale scars of terminal buds. It is possible to determine the age of a twig by the number by these rings formed by the bud scale scars of terminal buds. For example, a twig with one such ring is two years old, one with two rings is three years old, etc.

Close observation of the twig will reveal a number of whitish spots on the bark. These are *lenticels* (Fig. 12), structures on the stem composed of a mass of loosely fitting cells which permit the diffusion of gases inward and outward. Except for the lenticels, the bark prevents the free passage of air, and also the loss of water from underlying stem parts.

How Does a Stem Grow in Length?—As has been stated, a bud is a young shoot. A lengthwise section of a leaf bud shows a cone-shaped growing point (young stem) upon which

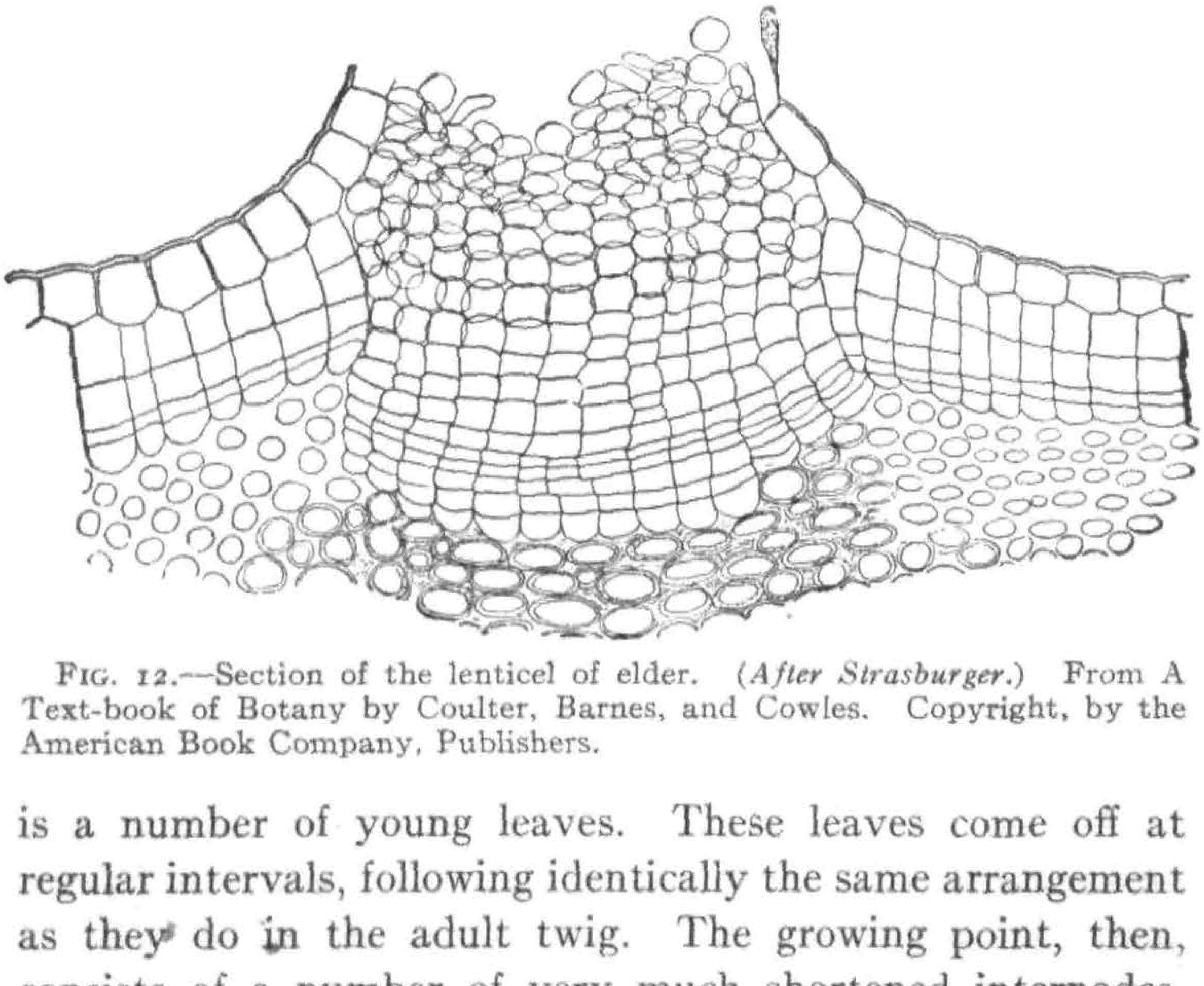


FIG. 12.—Section of the lenticel of elder. (*After Strasburger.*) From A Text-book of Botany by Coulter, Barnes, and Cowles. Copyright, by the American Book Company, Publishers.

is a number of young leaves. These leaves come off at regular intervals, following identically the same arrangement as they do in the adult twig. The growing point, then, consists of a number of very much shortened internodes. Growth in length of the shoot consists in the elongation of these internodes by increase in number and size of cells that compose internode tissue.

As a rule, the number of leaves that will be on a twig is already fixed in the bud. Seldom do new leaves originate during the growing season. This point is worthy of special

mention: When a twig has made its year's growth, the internodes do not lengthen thereafter during subsequent years. Increase in length of that shoot is due to the addition of other "joints" at the end. The fixed length of old internodes is well proven by the common observation that nails driven into the trunk of a tree, or a small branch, are not elevated above the ground as the tree grows. It will become grown over with wood, but its height above the ground remains the same. A common impression prevails that the branches of a young tree should be started near the ground, so that they will be at about the right elevation above the ground when the tree reaches maturity. The erroneous supposition here is that the limbs are raised by the growth of the tree.

Classification of Stems Based upon Their Medium of Growth.—The medium of growth of most stems is air. Such stems may arise from the soil as in nearly all of our ordinary plants, or they may have no attachment with the soil at all, receiving mechanical support from other plants. The latter are called *epiphytes*. *Tillandsia usneoides* is probably the best epiphyte among seed plants. It is the so-called "Spanish moss." Many orchids of the moist tropics are *epiphytic*.

The entire shoot system of some plants is underground. This is the case in the ferns. Many plants produce both aerial and subterranean stems. For example, Canada thistle has horizontal underground stems, and from these are sent up aerial shoots bearing foliage leaves and flowers. Both underground and aerial stems are possessed by such common plants as Irish potato, onion and asparagus.

Water is also a medium of growth of stems, as is the case with such plants as *Elodea*, *Potamogeton*, water lilies, etc.

"Modified" Stems.—Undoubtedly, the ordinary cylindrical twig such as is found in trees and shrubs is the most common sort of stem. It is quite likely that we think of a

stem as a plant part growing more or less erect, in fact, most stems do tend to grow erect. However, all stems are not as just described. As we take a survey of the plant kingdom, we discover many different forms of stems—stems that are

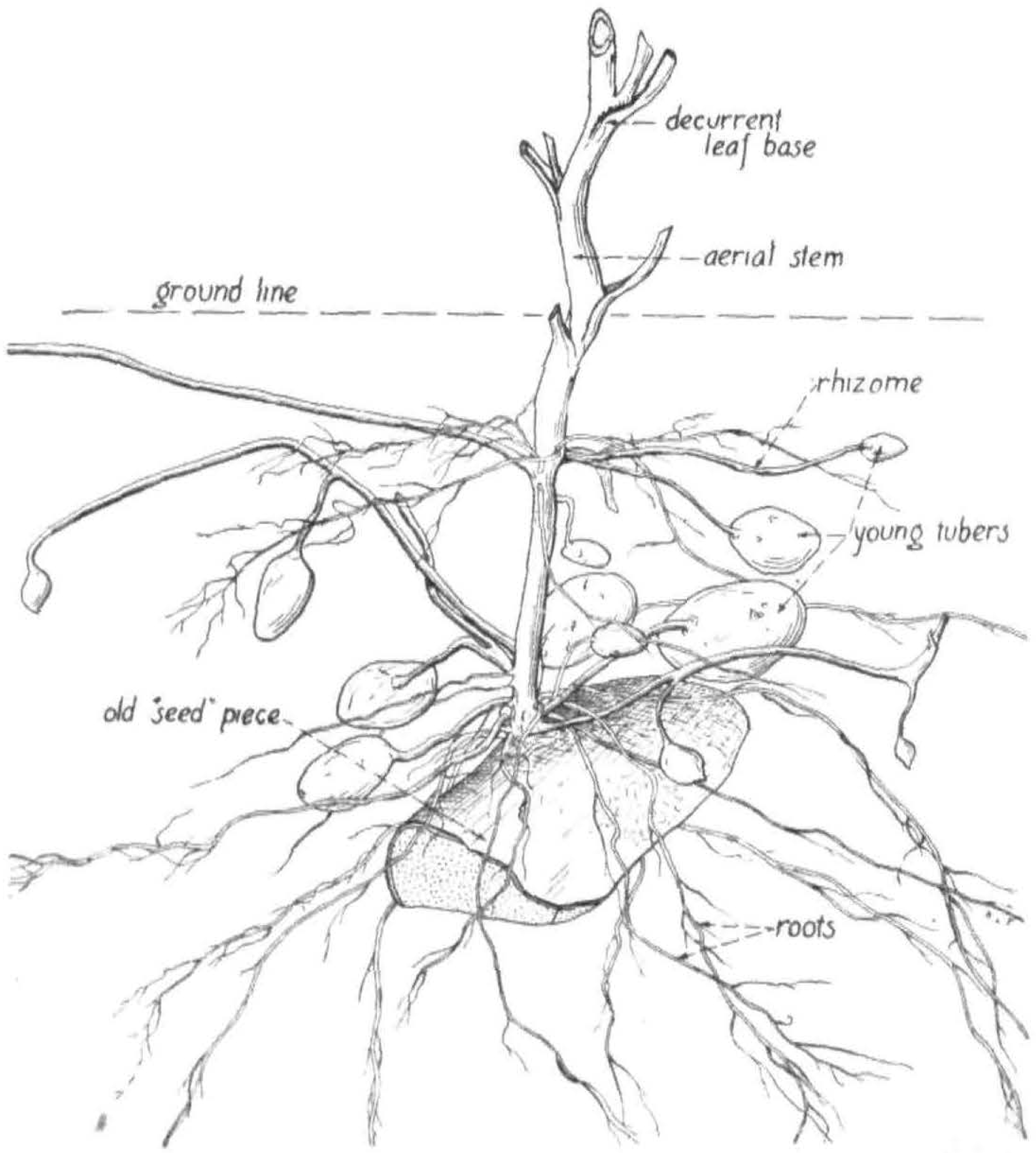


FIG. 13.—Portion of a sprouting potato tuber.

so different from the ordinary sorts that they are scarcely recognizable as stems, and are identified as such, only by careful study of their origin and structure. Among such stems are the following:

1. *Rootstocks or Rhizomes* (Fig. 13).—These are underground, horizontally elongated stems. The rootstocks or

rhizomes of Canada thistle are excellent examples. They bear reduced, scale leaves at the nodes. Lateral buds arise in the axils of these leaves, just as described in the cottonwood twig—a typical stem. They grow in length from a terminal bud, which is unprotected by tough scales. Adventitious roots are produced at the nodes. Rootstocks are efficient organs in the spreading of a plant. Here is a method of reproduction other than by seeds. Usually, aerial stems from the lateral buds of the rootstock are produced; they may die back to the ground each fall. The plant lives over the winter by means of the rootstocks. Hence, rootstocks or rhizome-bearing plants are perennial. Many of our worst weeds are perennials from a rootstock. We may prevent such plants from going to seed, but in spite of this, and the cutting back of the leafy shoots, new shoots are sent up from the rootstocks. Furthermore, if the rootstocks are broken into a number of separate pieces by cultivating implements, each piece may develop adventitious roots, establish itself, and send up leafy shoots. Frequent cultivation that has as its aim the destruction of new shoots as soon as they appear, may succeed in starving out the rootstock after a time. The period of time depends upon the amount of stored food material in the structure. This method of eradication is based upon the knowledge that the food of the plant is manufactured in the chlorophyll-bearing (green) cells above ground.

2. *Tubers.*—These are fleshy, underground stems. The best example is common Irish potato. Although the potato, ordinarily, would not be considered a stem, still if we follow through its development, and examine its structure, we are convinced that it is stem (Fig. 13). When we plant a slice of a potato, "sprouts" are soon sent out from the "eyes." These sprouts, with their nodes, and internodes, and their scale leaves, are quite obviously horizontal under-

ground stems (rhizomes). Soon, the tip of a rhizome begins to enlarge, and a potato is formed; hence, the potato is seen to be a simple enlargement of the tip of an underground stem. Furthermore, examination of the tuber reveals the presence of a terminal bud ("seed end" of the potato), and lateral buds along the sides. The buds are the so-called "eyes." In an elongated potato, we may be able to detect the spiral arrangement of the buds. Lenticels may also be observed on the corky layer (skin) of the bark of the potato.

A section of a tuber reveals a stem structure. The three principal parts of an ordinary stem are bark, wood and pith. This is shown in a cross-section of an ordinary twig (Fig. 14). In the potato, these three distinct zones are visible, as indicated in Fig. 236. Hence, we see that the potato is in reality a modified stem.

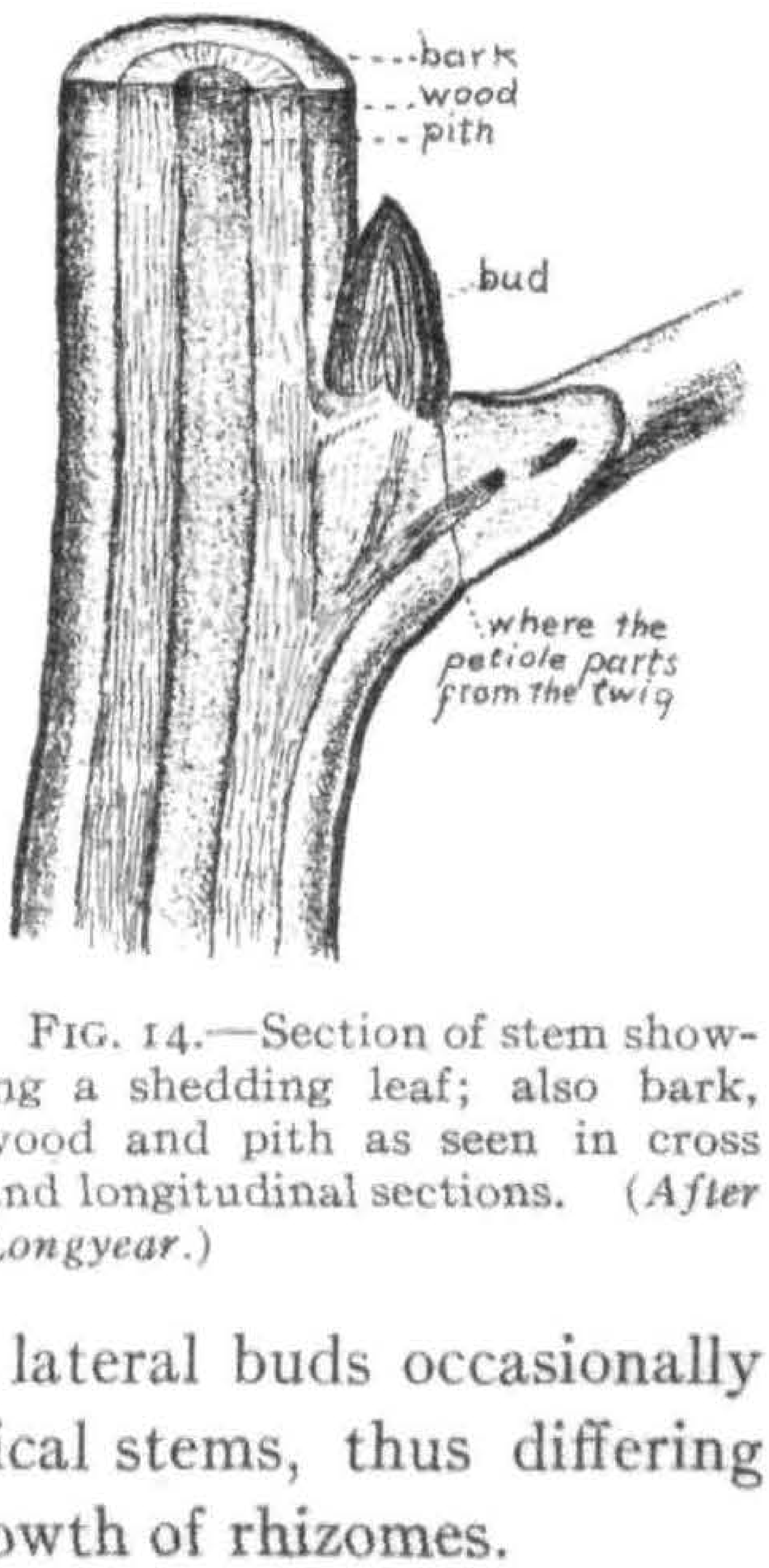


FIG. 14.—Section of stem showing a shedding leaf; also bark, wood and pith as seen in cross and longitudinal sections. (*After Longyear.*)

3. *Bulbs.*—The common onion is a typical example of a bulb. A median, lengthwise section (Fig. 15) of the onion bulb, shows a small, cone-shaped stem upon which are numerous, fleshy leaves that are over-lapping and quite rich in food material. Here, too, there is a terminal bud, and lateral buds occasionally in the leaf axils. Bulbs are vertical stems, thus differing from the horizontal direction of growth of rhizomes.

4. *Corms.*—A corm is a short, solid, vertical, underground stem. It is typically exemplified in gladiolus. Corms are usually flattened from top to bottom, and bear a cluster of thick fibrous roots at the lower side, and a tuft of leaves on the upper side. Corms are storage organs.

5. *Runners* (stolons).—These resemble rhizomes in that their direction of growth is horizontal. In the strawberry plant, the branches that arise from the axils of the closely set leaves are called "runners." They are slender stems, growing along the ground surface; they have long internodes, and produce leaves, flowers and roots at the nodes.

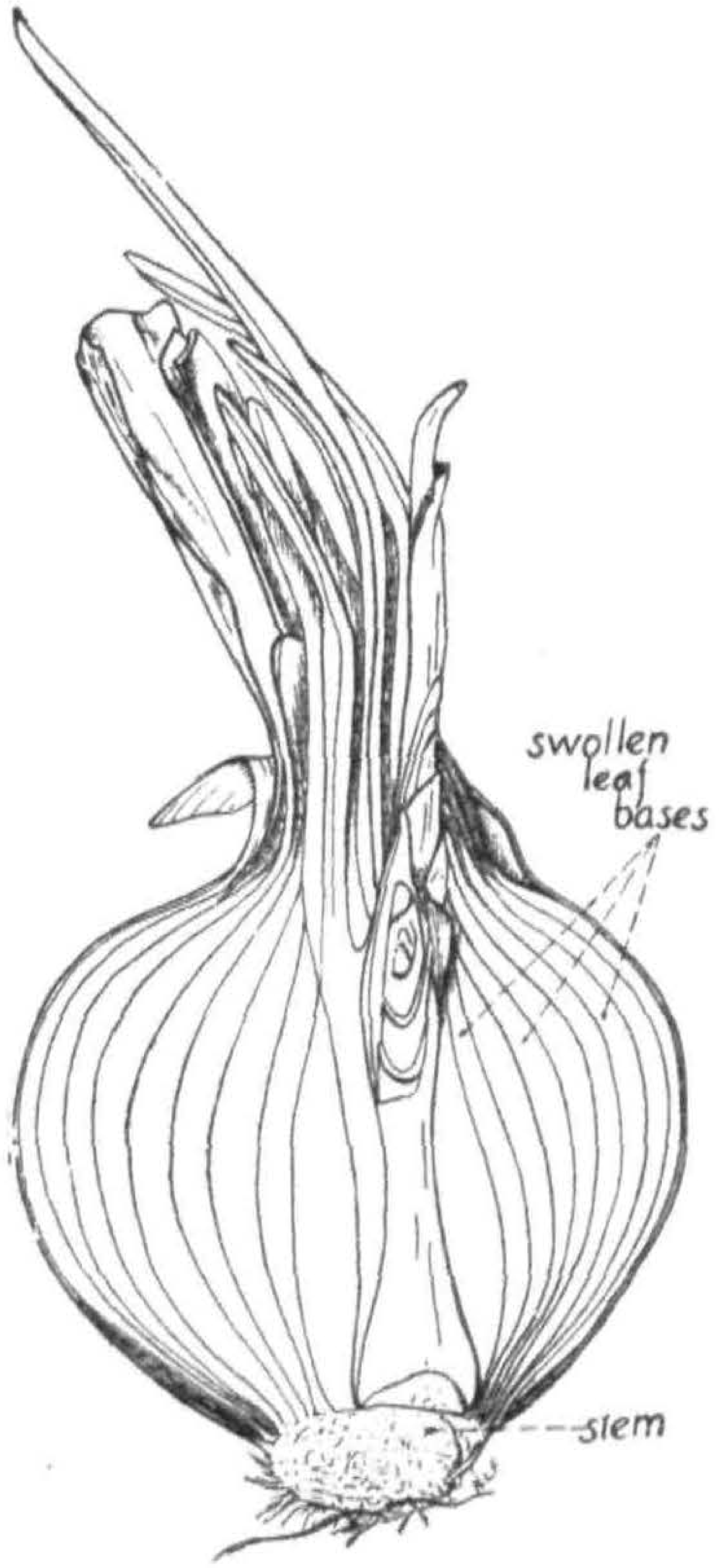


FIG. 15.—Median lengthwise section of common onion bulb.

6. *Lianas*.—A liana is a climbing stem, gaining mechanical support only from another plant. Common lianas are the grape, Virginia creeper, hop, Japan ivy (*Psedera tricuspidata*) and morning glory. The stems of lianas are slender, long, and have insufficient strengthening tissue to hold them perfectly erect. The twining stem of Virginia creeper bears fleshy, yellowish air roots which may aid the plant in adhering to its support. Of greater value to the Virginia creeper plant, in this regard, however, are the highly specialized branches—*tendrils*. In this case, a tendril ends in a knob which flattens out, when it comes into contact with a surface, and adheres to that surface by a mucilaginous disk-shaped structure.

7. *Spines*.—Some spines are reduced stem structures, as is the case in the honey-locust, hawthorn, wild crab, etc.

Many small spines, such as are found in gooseberries, cacti, and roses, for example, are outgrowths of the stem. It seems that the development of spines is induced by an excessive loss of water from the plant, and a low absorption rate, such as occur under desert and semi-desert conditions.

STRUCTURE OF STEMS

The Young Dicot Stem.—Let us cut a middle lengthwise section of a young dicot stem (Fig. 16). This section will cut the growing point (bud) of the stem, and the older parts back of the growing point. We see that the stem becomes progressively older farther and farther back from the tip. The cells at the growing point make up a tissue known as *meristem tissue*. Although these cells are similar in appearance, they are capable of developing into different tissues. Just back of the growing point, we note that the primordial meristem cells have differentiated into three main regions: *protoderm, ground meristem,* and *procambium strands.* These three regions are best shown in a cross-section (Fig. 16). In a little older portion of the stem, such as shown in a section further back (Fig. 16), further differentiation has taken place, which changes involve the ground meristem and the procambium. The vascular bundle is composed of three regions: *phleom, cambium* and *xylem.* The center of the stem is made up of large, loosely fitting cells which constitute the pith or *medulla.* Radiating from the medulla out between the vascular bundles are a number of cells which make up the *medullary ray.*

Dicot Vascular Bundle.—Detailed examination of a dicot vascular bundle in cross- and longitudinal sections shows each of its three parts to be made up of characteristic structural elements.

Phloem.—In the phloem are *sieve tubes, companion cells, phloem parenchyma* and *phloem fibers* (bast). Each sieve

tube is a single cell, much elongated and modified for conduction. The end walls of sieve tubes (Fig. 17) are thickened,

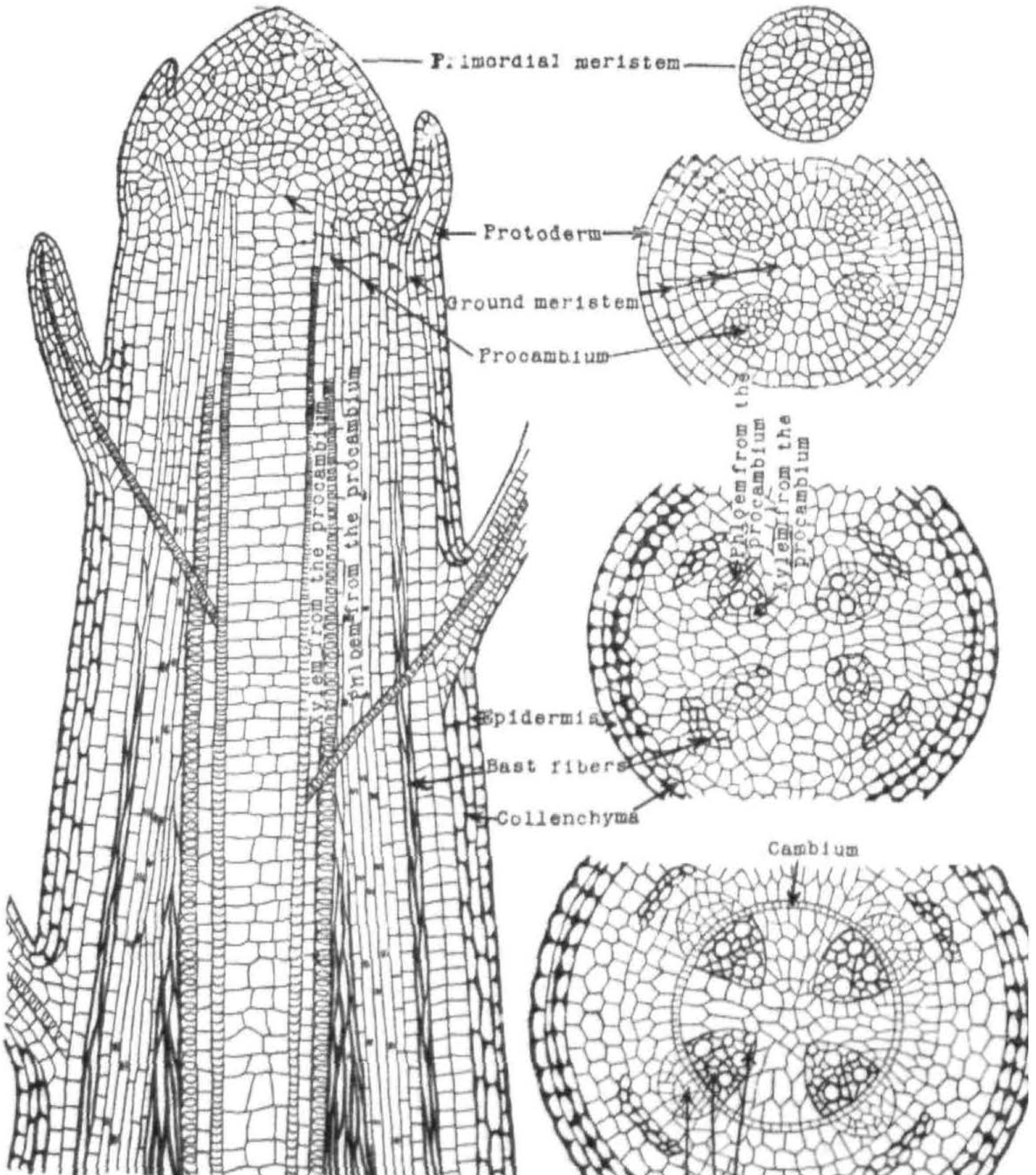


FIG. 16.—Diagram showing the evolution of tissues from the primordial meristem down to the beginning of cambial activity. (*After Stevens.*)

and perforated by a great number of holes, and thus resemble a sieve. Each sieve tube is adjoined by a single row of small cells, the *companion cells*, which run parallel to it. Phloem

parenchyma cells are somewhat vertically elongated, but they do not reach any considerable size. Phloem or bast fibers are single, elongated and tapering cells with relatively thick, lignified walls.

Functions of Phloem Elements.—The functions of these three elements of the phloem are as follows:

1. *Sieve Tubes.*—Conduction of soluble carbohydrates, amino-acids and proteins.

2. *Companion Cells.*—Although sieve tubes lose their nuclei before the end of the first year, they do not die; hence, it is thought that companion cells extend their influence to the sieve tubes, enabling them to carry on the life processes for which a nucleus seems necessary.

3. *Phloem Parenchyma.*—The cells of this region store food material or conduct it short distances in the stem.

4. *Phloem or Bast Fibers.*—Give strength.

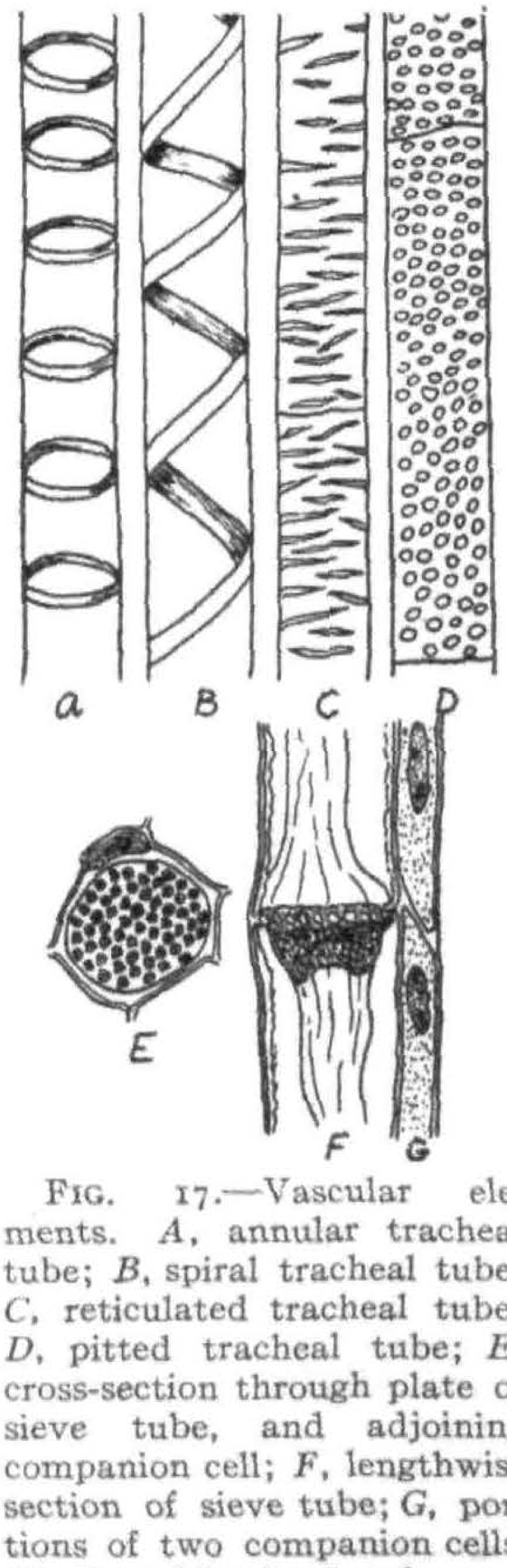


FIG. 17.—Vascular elements. *A*, annular tracheal tube; *B*, spiral tracheal tube; *C*, reticulated tracheal tube; *D*, pitted tracheal tube; *E*, cross-section through plate of sieve tube, and adjoining companion cell; *F*, lengthwise section of sieve tube; *G*, portions of two companion cells. (*E*, *F*, and *G* *after Strasburger.*)

Cambium.—The cambium layer is composed of one or more rows of small cells, flattened in planes that run at right angles to a radius of the stem. They are thin-walled cells, rich in protoplasm, and capable of rapid cell division and growth. The *cambium is in fact the growing layer of the stem.* In grafting, one stem, the *scion*, is inserted into another stem, the *stock*, in such a way as to bring the two cambium

layers together. After a time there is a union of the cells of these layers.

Xylem (Wood).—The chief structural elements of the xylem or wood portion of the vascular bundle are: *tracheal tubes, tracheids, wood fibers* and *wood parenchyma.* The tracheal or water tubes are long, large, tubes with thick walls. They have been formed by the elongation and enlargement of rows of cells, the common end walls of which have totally or partially dissolved, leaving a duct of considerable length. The walls of the tracheal tubes become thickened, and the thickening material is laid down on the inside of the walls in various patterns. The thickening material is of the nature of cellulose. Subsequent to thickening, physical and chemical changes occur known collectively as lignification.

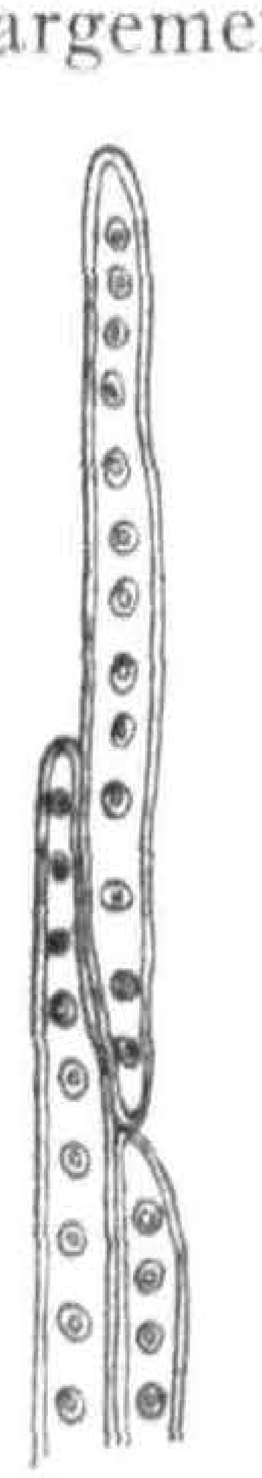


FIG. 18. Tracheids with bordered pits.

Kinds of Tracheal Tubes (Fig. 17).—There are the following sorts of tracheal tubes:

1. *Annular Tracheal Tubes.*—Here and there in the tube are thickened rings of lignin, which have the appearance of barrel hoops.

2. *Spiral Tracheal Tubes.*—The thickening material is in the form of a loose spiral.

3. *Reticulated Tracheal Tubes.*—In these, the strengthening material is laid down in such a fashion as to form a network on the wall.

4. *Dotted or Pitted Tracheal Tubes.*—In these, lignin has been deposited over the inner wall in such a manner as to leave numerous circular thin places, which give the tube a dotted or pitted appearance.

Tracheids (Fig. 18) are single elongated cells. They have thick, lignified walls with numerous *bordered pits.* In shape tracheids are like a spindle, and they fit closely together making up a strong supporting tissue.

Wood parenchyma cells are usually thin-walled and with unbordered pits.

Wood fibers are long, taper-pointed at the ends and thick-walled. They may have simple or bordered pits.

Functions of Wood Elements.—The functions of the different wood (xylem) elements are as follows:

1. *Tracheal Tubes.*—(*a*) Carry water and solutes from the soil to and throughout the leaves; (*b*) give strength to the stem.

2. *Tracheids.*—(*a*) Carry water and solutes; (*b*) give strength to the stem.

3. *Wood Parenchyma.*—(*a*) Store water and foods; (*b*) and also conduct them short distances.

4. *Wood Fibers.*—Give strength to the stem.

Growth in Thickness of Dicot Stem.—Medullary ray cells give rise to cambium that joins with the cambium in the vascular bundles. Thus there is formed a continuous *cambium ring* (Fig. 16). At the end of the first year of growth or the beginning of the second, *cork cambium* is differentiated in the outer cortex. Growth in thickness of the stem consists then in the production and growth of new cells from: (1) cambium of vascular ring, and (2) cork cambium. The cambium cells of the vascular ring may differentiate into xylem, or phloem, or remain cambium. Each cambium cell divides by a wall which is parallel with a tangent to the surface of the stem. If the inner daughter cell resulting from the division becomes a xylem element, the outer usually remains cambium. On the other hand, if the outer daughter cell resulting from the division becomes a phloem element, the inner remains cambium. Hence, by a division of cambium cells of the vascular ring, new xylem is laid down on the outside of the old xylem, and new phloem is laid down on the inside of the old phloem. Not only do the vascular bundles grow in a radial direction, but also somewhat laterally.

This lateral growth of existing vascular bundles, together with the formation of new ones between the old ones, brings about a narrowing of the medullary rays, so that in an old stem they appear as mere lines or rays radiating from the pith or medulla. And, furthermore, the wood comes to form quite a solid ring, as does also the phloem.

In addition to the increase in stem thickness by the production of more xylem and phloem, the cork cambium cells aid in this process. Cork cambium cells which divide by a wall that is parallel to a tangent of the stem, give rise to *cork tissue*, and to *secondary cortex*. Hence, each year, there are produced in the dicot stem:

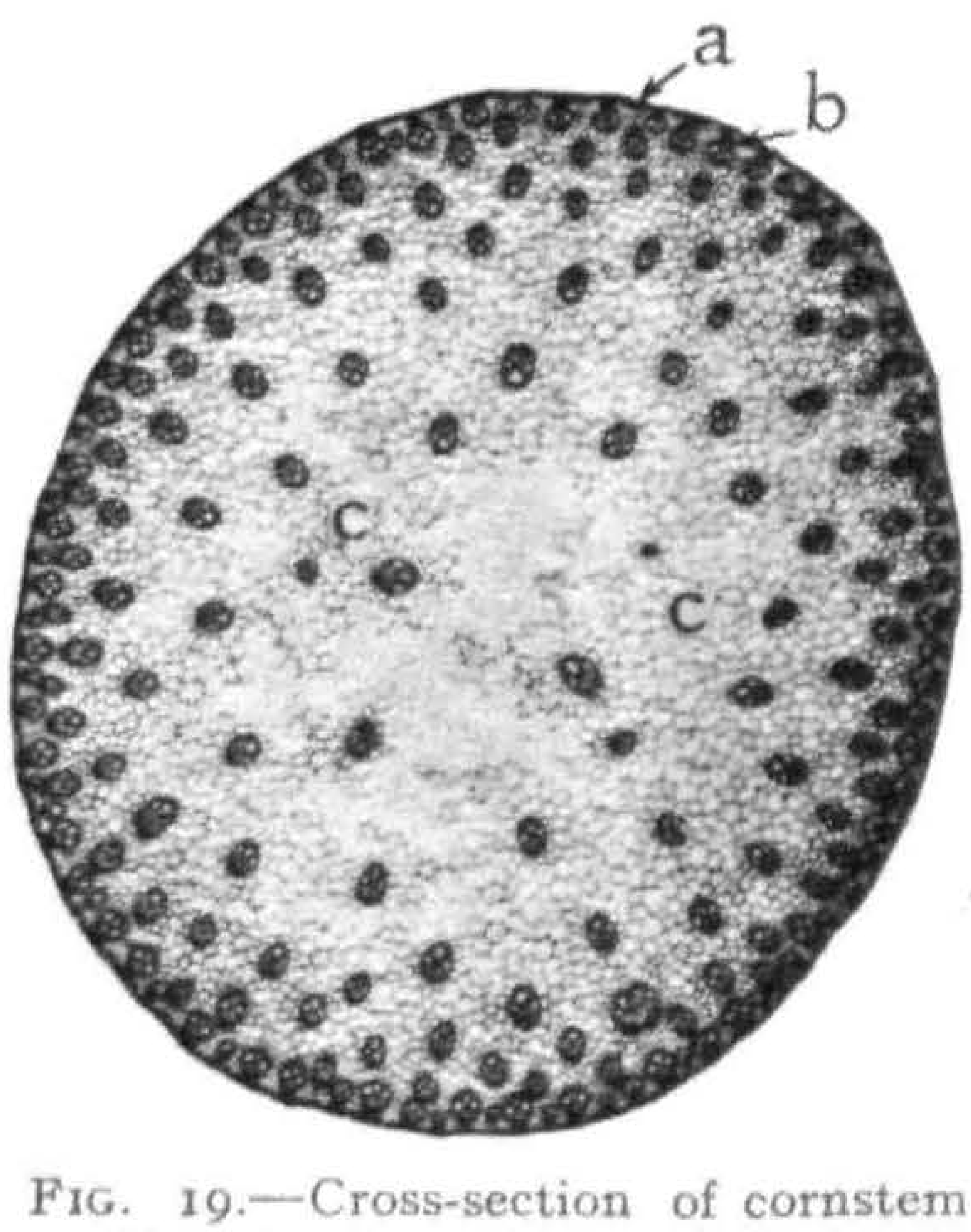


FIG. 19.—Cross-section of cornstem; *a*, epidermis; *b*, cortex and pericycle; *c*, ground tissue. (*After Stevens.*)

1. Wood, on outside of old wood.
2. Phloem, on inside of old phloem.
3. Cork, on inside of old cork.
4. Secondary cortex, on outside of old cortex.

A two-year old woody dicot stem has the following general structure:

1. *Bark*, consisting of the following parts in order from outside to inside: Cork, cork cambium, secondary cortex, primary cortex, primary phloem, secondary phloem.
2. *Cambium* of vascular bundle.
3. *Wood*, consisting of two layers, the youngest toward the outside.
4. *Pith.*
5. *Medullary rays*, each ray of several rows of thin-walled cells.

Monocot Stems.—The corn stalk is an excellent type of a monocot stem. In this, as shown in cross-section of the stem in Fig. 19, the vascular bundles (fibers) are scattered throughout the ground tissue. They do not form a definite "vascular ring" as in dicot stems. Moreover, the vascular bundles of most monocots do not possess cambium, as in dicot stems. Hence, new phloem and xylem are not produced each season, and consequently there are no annular rings formed. Growth of monocot stems results from (1) simple enlargement of cells derived from primary meristem tissue, and in some instances from (2) the formation *de novo* of vascular bundles from cells that have retained their meristematic power.

Annual Rings.—An annual ring, as generally understood, is one year's growth of wood (xylem). The ring varies in width, depending upon the time in the life of the plant it was formed, and upon seasonal climatic conditions. Furthermore, it is known that some trees grow rapidly, producing wide annual rings, while it is a specific character of others to grow slowly, *i.e.*, produce narrow annual rings.

There is usually a marked difference in the wood formed in the spring and early summer, and that produced in late summer and fall. In early or so-called "summer wood," tracheal tubes are large and quite numerous; in late or "autumn wood," tracheal tubes are smaller and fewer, and tracheids and wood fibers are relatively more abundant. Hence, "autumn wood" has more strength than "summer wood." It is readily seen that the autumn wood of one year (say 1916) is adjacent to the spring wood of the following year (1917). "Soft wood" is usually one which grows rapidly, and is *diffuse porous*, that is, tracheal tubes are rather small and uniform in size and evenly distributed throughout the year's growth. "Hard wood" is usually a comparatively slow-growing wood, and is *ring oprous*, that

is, the tracheal tubes of the spring and early summer are large and numerous, while the autumn wood is solid as a consequence of the relatively greater abundance of tracheids and wood fibers.

Bark.—The term "bark" as used here includes all that portion of the stem down to the cambium layer. When the bark of a tree is peeled off, there are removed the following layers in order from outside to inside: cork, cork cambium, cortex, pericycle, phloem, and portions of cambium. The cleavage line is the cambium zone.

The Work of Stems.—(1) The stems of trees, shrubs and common herbs are mainly concerned in the *conduction of water and solutes from the soil, and of food materials.* The need for a conductive system first arose in the plant kingdom when the food-making organs of the plant became elevated above the soil or water surface. (2) The stem also is a support to the other organs of the plant, and it brings into display the leaves, and flowers. The leaves are brought into a position where they may receive the light to advantage, and flowers are placed where their pollen may be disseminated by wind or bees, and seeds may be more easily spread. (3) In addition to conduction and support, stems may store food material, water and various waste products. In our woody perennials, such as the apple or peach, for example, an abundance of food material is stored during the winter in the medullary ray cells, also, in wood parenchyma, and in that portion of the pith adjacent to wood, and sometimes in all of the pith cells; portions of the phloem and cortex may also store food. The stems of such plants as the giant cactus, and other cacti, store large quantities of water. Some stems, such as the potato tuber, bulb, corm and root-stock, are heavily loaded with stored food material. (4) Young stems that contain chlorophyll in their outer layers possess the power of manufacturing carbohydrates, just as do green leaves.

CHAPTER V

LEAVES

Development of Leaves.—Leaves appear at the growing point of a stem, as lateral protuberances (Fig. 16) consisting at first of a shapeless mass of cells. We call this group of cells the *leaf primordium*. By further cell division and differentiation of these few cells the adult leaf arises. In the embryos of seeds the first few leaves are already formed, and even in this early stage may bear some resemblance in shape to the adult leaves.

Parts of Leaf.—Most leaves have two distinct parts: *blade* and *petiole* (leaf stalk). Some leaves, as those of peas and beans, have two small, leaf-like structures at the base of the petiole which are the *stipules* (Fig. 20). The petiole is sometimes absent, the blade being mounted directly on the stem. Such a leaf is said to be *sessile.* Vascular bundles run from the stem out through the petiole into the blade, where they branch to form the *network of veins.* The veins not only carry water, solutes and food materials, but also form a framework for the softer tissue of the leaf.

Kinds of Leaves.—It is possible to classify leaves in many different ways. Common green leaves that we are all familiar with are usually called *foliage leaves.* They are the chief food-making organs of all ordinary plants. However, there are many leaves that do not possess green coloring matter (chlorophyll) and hence, have no food-making power. As examples of the latter, may be mentioned the small, scale leaves on underground stems, the scales enwrapping

the growing point in buds, the bracts in grass inflorescences, and the petals, stamens and carpels of flowers.

FIG. 20.—A single compound leaf of sweet pea.

We look upon ordinary foliage leaves as the most common, and hence "normal" sorts of leaves. We would regard scale leaves, bracts, bud scales, and flower parts as "modified" leaves.

Leaves may function as (1) food-making organs (foliage leaves), (2) protective structures (scales), (3) reproductive organs (floral organs), and (4) as storage organs. The fleshy leaves that make up the bulb of onion are good examples of leaves used for storage.

Foliage leaves are either *parallel-veined* or *netted-veined*. In leaves with parallel venation, there are many veins, about equal in size, running parallel, and joined by inconspicuous veinlets. This type of venation is characteristic of the leaves of grasses, sedges, rushes, lilies and most all other monocotyledonous plants. In leaves with netted venation, which is so well illustrated in leaves of apple, oak, maple, potato, cabbage and other dicotyledonous plants, there are a few prominent veins from which arise numerous minor veins, thus forming quite a conspicuous network.

Leaves are often classed as *simple* or *compound*. The apple leaf is an example of a simple leaf (Fig. 163). In this there

is an undivided blade. The bean, pea, carrot or parsnip leaf is compound (Fig. 20). The blade is divided into a number of segments, or *leaflets*.

We may classify leaves as to their arrangement on the stem. Leaf arrangement is the same as bud arrangement, for ordinarily a bud arises in the axil of each leaf. They may be alternate, opposite or whorled (see page 25).

Leaves vary widely in size, shape, character of margin, and base, texture, thickness, nature of epidermal coverings, etc. Some of these variations will be mentioned throughout the pages that follow.

Structure of Leaves.—The structure of a leaf is best shown in a cross-section (Fig. 21). The *upper epidermis*, usually consists of a single row of cells. Below it, is the *palisade layer*, composed of one or more rows of cells the long axes of which are perpendicular to the leaf surface. Below the palisade cells is the *spongy parenchyma*, varying in thickness, and composed of rather irregularly shaped cells that fit together loosely, thus leaving *intercellular spaces* (air spaces). The *lower epidermis* is seldom more than one layer of cells thick. Chloroplastids are abundant in palisade and spongy parenchyma cells, but absent from all epidermal cells except the guard cells of stomata.

The outer wall of epidermal cells is normally thicker than radial or inner walls. Cutin, a fatty substance, highly impervious to water, is deposited on the outer wall, to form a layer called the *cuticle*. A thick cuticle is a common characteristic of leaves growing in arid situations. The same variety will develop a thicker cuticle under arid conditions than when growing where there is ample water. A thick cuticle is a good drought-resistant character.

The epidermal cells do not form a continuous layer over the two leaf surfaces, but there are numerous pores or openings, the *stomata* (singular *stoma*, a mouth) (Fig. 21). Each

stoma is bounded by two modified epidermal cells, differing from ordinary epidermal cells in form, in their ability to change shape, and in the possession of chloroplastids. These are the *guard cells*.

Leaves possess many different kinds of surface peculiarities, such as hairs, scales, wax and resin deposits. These are features which tend to retard water loss from the leaf surface.

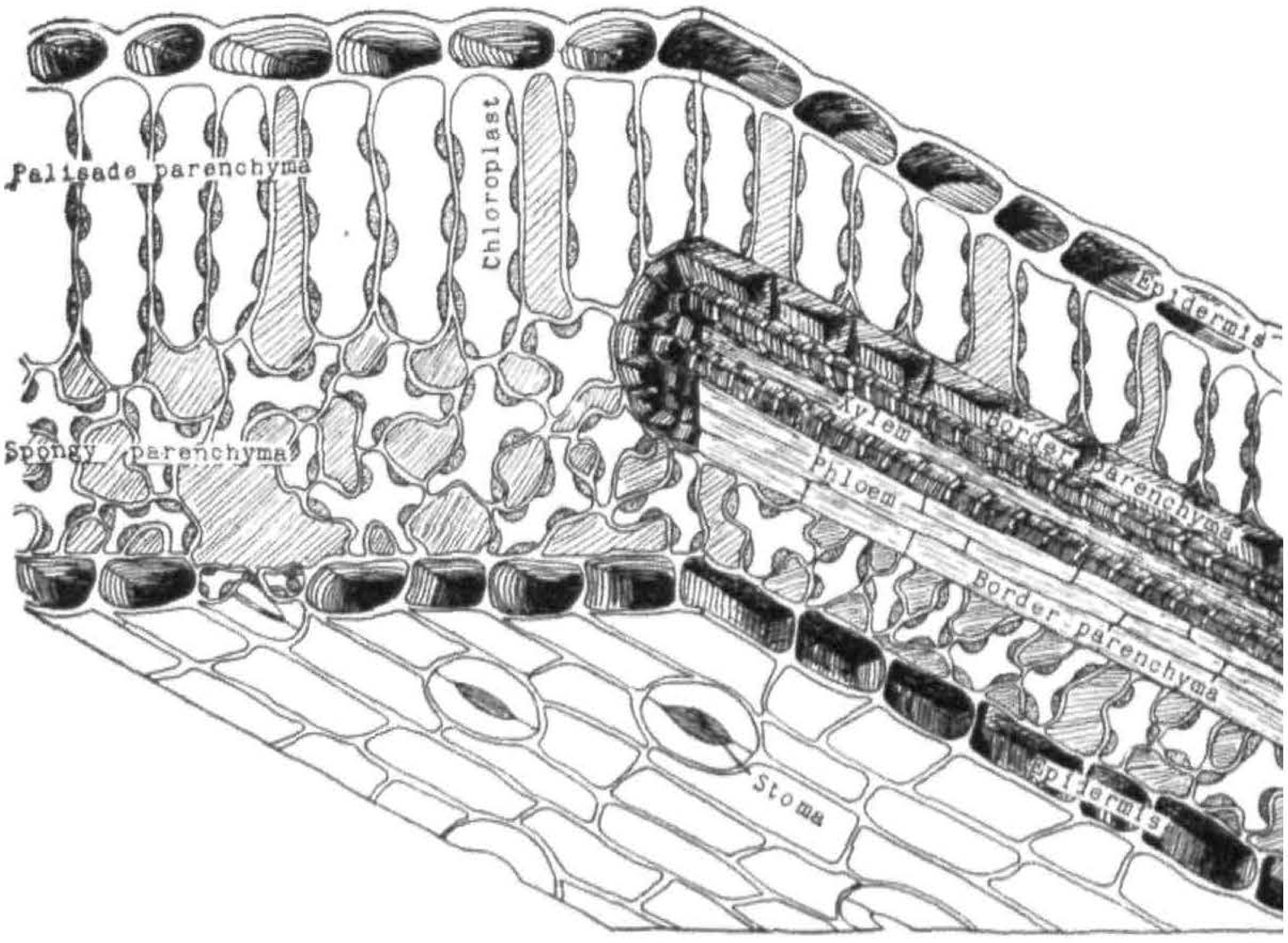


FIG. 21.—Diagram showing the structure of a representative leaf. (*After Stevens.*)

There is the widest variation in leaf structure. That described above is typical of dicot leaves growing in situations with a moderate water supply. Water leaves are thin and have no palisade tissue. Palisade tissue is also absent in the leaves of grasses. The leaves of plants growing in arid situations are usually thick. The increased thickness is commonly due to an increase in the number of rows of palisade cells. Palisade may develop on both upper

and lower surfaces. Some leaves have palisade tissue from epidermis to epidermis. The thickness of leaves growing in arid conditions may also be, in part, the result of the development of a very thick *cuticle*.

The Work of Foliage Leaves.—We are all familiar with the injury to a plant that results from defoliation through any cause, or from disease of leaves, or from their meager development. We have learned to associate an abundance of bright green leaves with plant vigor, just as we associate a rosy complexion with health in people. And, with but few exceptions, we may judge of the health of a plant by its leaf development and color.

Carbohydrates are made by green plants only, and only by those cells of green plants that possess chlorophyll. The cells of roots and other underground plant parts, and all those cells of the plant so far removed from the surface as to be beyond the influence of light, do not have chlorophyll, and hence, have no power of making carbohydrates. Other than that in the relatively small amount of green tissue in young stems and in the sepals of flowers, all the carbohydrate of the plant is made in the chlorophyll-bearing cells of leaves. The manufacture of carbohydrate by green tissue is called *carbohydrate synthesis* or *photosynthesis*. When we realize that carbohydrates form the basis of all the other more complex foods of the plant body, such as fats, amides and proteins, we see the great importance of a healthy leaf development.

In addition to their important work of carbohydrate synthesis, the synthesis of the fats, amino-acids and proteins is carried on to a large extent in leaf cells. We may truly say, then, that leaves are the food-making organs of a plant.

Leaves are also the chief transpiring (water-losing) organs of the plant. Practically all of the water that escapes from a plant passes out through the leaves, chiefly through the

stomata. When in a healthy growing condition, there is a continuous stream (transpiration stream) of water from the roots to the leaves.

The leaves of many succulent plants, such as Agave, Russian thistle, salt wort, stone crop, and others serve as storage places for water. Agave leaves may also store food. The onion bulb is made up of a very short stem bearing numerous, overlapping, fleshy leaves in which considerable quantities of food are stored.

The leaves of the sundew (*Drosera*), and pitcher plants (*Sarracenia* and *Nepenthes*) are highly modified as special organs that catch, digest and absorb insects.

CHAPTER VI

FLOWERS

Parts of Representative Flower.—A representative flower such as shown in Fig. 22 has the following parts taken in order from the outside to the inside:

1. *Calyx*, made up of *sepals*, which are green, and enclose the other flower parts in the bud.

2. *Corolla*, made up of *petals*, which are usually the colored portions of the flower.

3. *Stamens*, each made up of a *stalk* or *filament* at the tip of which is the *anther*, bearing *pollen grains*.

4. *Pistil*, which has a swollen basal portion, (1) the *ovary*, (2) a *style*, slender stalk leading from the ovary, and terminating in (3) a *stigma*, which is receptive to pollen. Within the ovary are the young *ovules*, the bodies which become seeds.

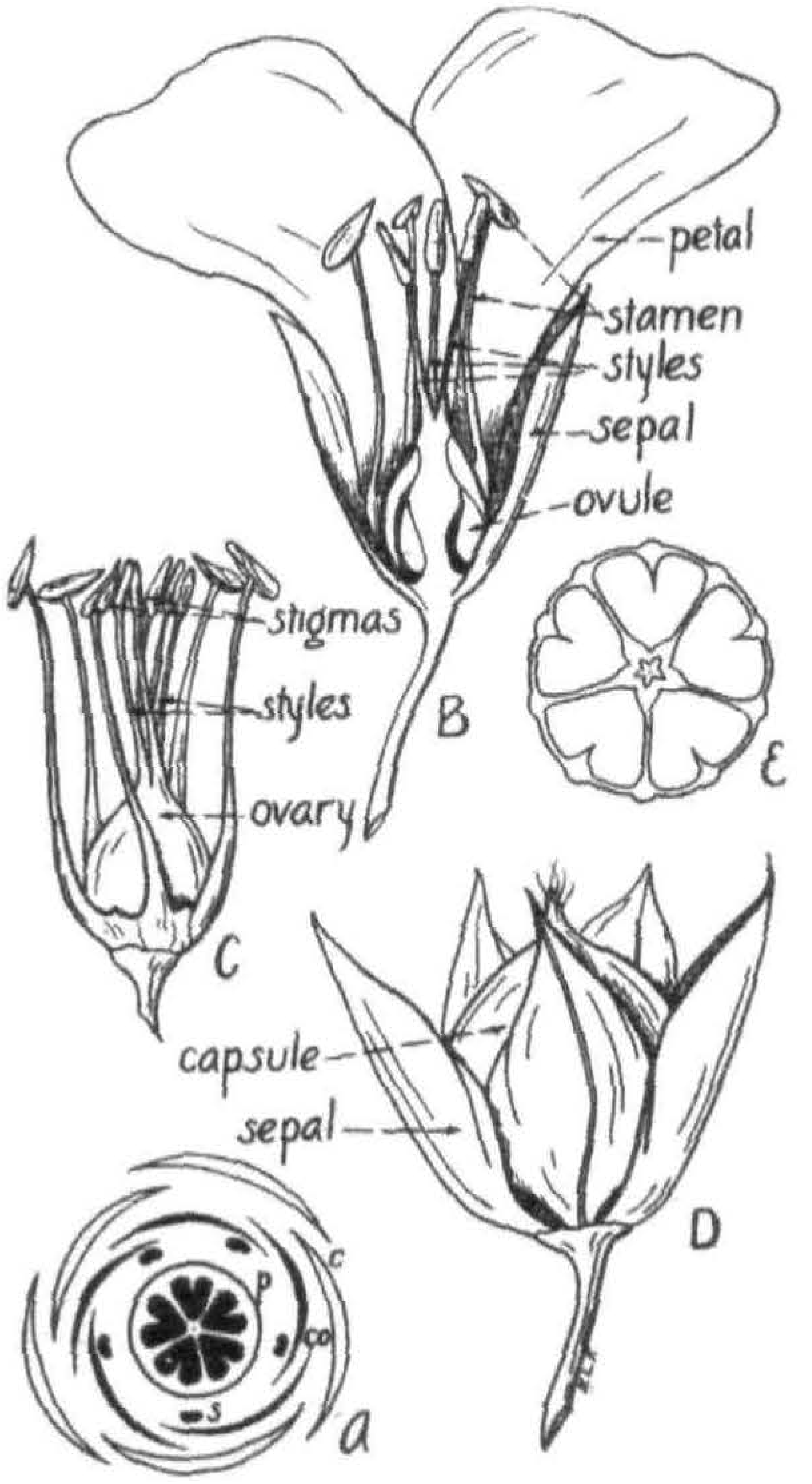


FIG. 22.—Flax. *A*, floral diagram—*c*, calyx; *co*, corolla; *s*, stamens; *p*, pistil. *B*, median lengthwise section of flower. *C*, calyx and corolla removed. *D*, fruit, external view. *E*, cross-section of fruit.

All the flower parts mentioned above, in the representative flower, are attached to the end of the flower stalk, the

receptacle or *torus*. The calyx and corolla taken together constitute the *perianth*.

We shall see that there are many different sorts of flowers in the families of seed plants. They differ widely in size, form, color, and in the shapes of the various parts.

Development of the Flower.—The primordia of flower parts arise as protuberances from the young receptacle (Fig. 16). As a rule, the sepals, petals, stamens and carpels appear in the order named, as described in the case of the

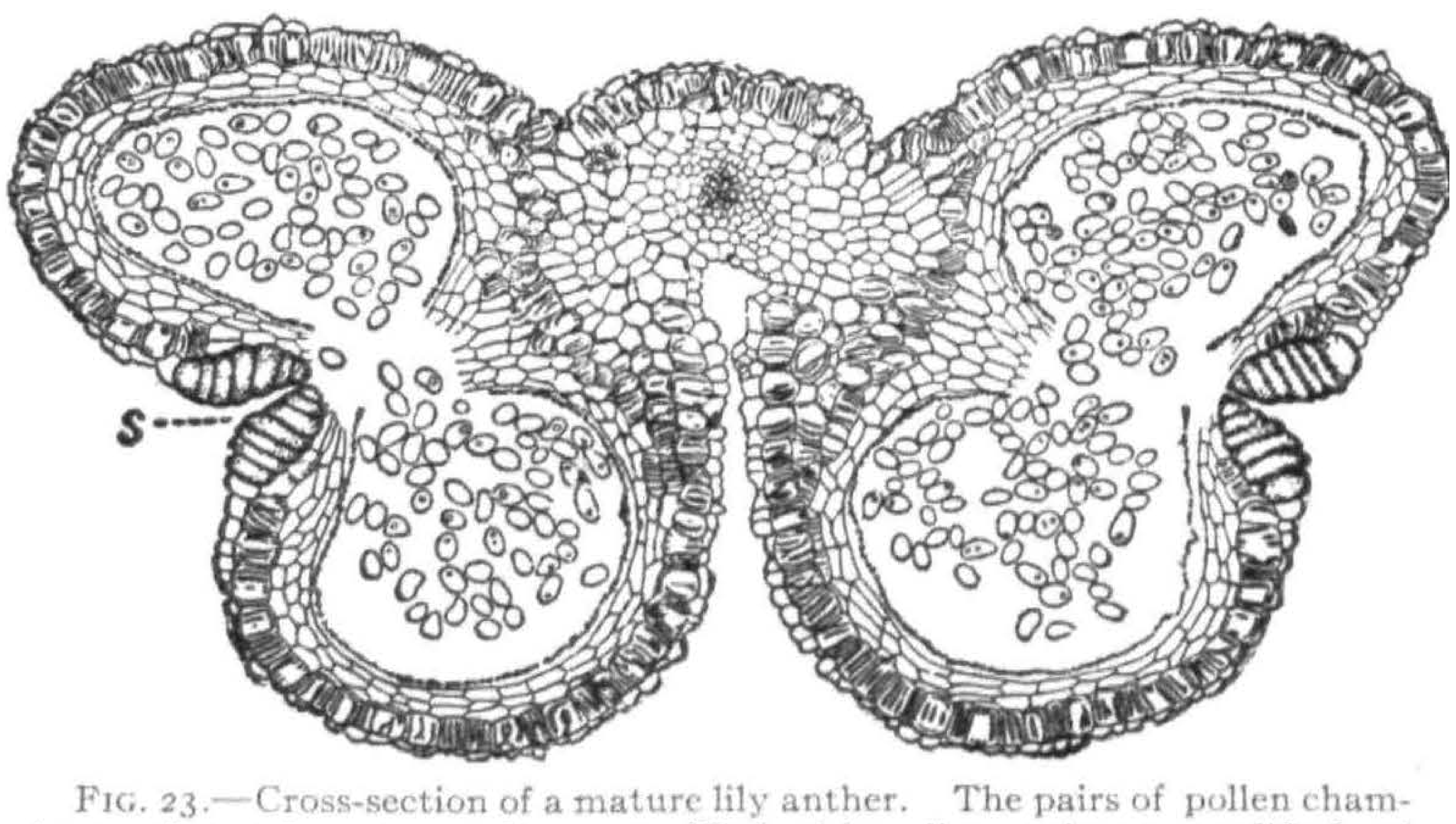


FIG. 23.—Cross-section of a mature lily anther. The pairs of pollen chambers unite to form two pollen sacs, filled with pollen grains; *s*, modified epidermal cells at line of splitting. (*From a Text-book of Botany by Coulter, Barnes, and Cowles. Copyright by the American Book Company, Publishers.*)

apple flower on page 369. This order of floral succession is said to be *acropetal*. Although this is the prevailing order, there are different types. For example, in some mustards the petals are the last to appear, and in some roses the carpel primordia appear before the stamens.

Stamens.—Ordinarily, the anther is held upon a *filament* or *stalk*. When the filament is absent, the anther is said to be *sessile*. A cross-section of an immature anther is seen to have four chambers or locules, each with a number of *pollen mother cells;* each pollen mother cell normally

divides to form four pollen grains. As the anther matures the pairs of locules unite, thus forming two pollen sacs in each anther. Finally, each sac splits open (dehisces) allowing the pollen to escape (Fig. 23).

Mature Pollen Grain.—When the pollen grain is mature, it consists of a wall surrounding a protoplasmic mass, the essential parts of which are a *tube nucleus* and a *generative nucleus*. Usually at the time of pollen germination the latter divides into two *sperm* or *male nuclei*.

Pistil.—The pistil usually consists of an ovary, style and stigma. The seeds are borne in the ovary. A cross-section of a *simple ovary* shows it to have one locule or chamber with one or more ovules attached to the wall. The tissue to which the ovule or ovules are attached is the *placenta*. A *compound ovary* (Figs. 22 and 135) usually has two or more compartments, with an ovule-bearing tissue (placenta) in each. We may also speak of the pistil as *simple* or *compound*. A simple pistil has one carpel, which is in reality a modified leaf bearing one or more seeds. A compound pistil has two or more carpels. When the carpels are separate, as in the strawberry (Fig. 155) the flower is said to be *apocarpous;* when united, as in asparagus (Fig. 99), *syncarpous*.

Ovule.—Fig. 24 shows an ovule just before fertilization. A central mass of tissue, the *nucellus*, is surrounded by an *inner* and an outer *integument*, except for a small opening, the *micropyle*. Within the nucleus is the *embryo sac*, at this stage consisting of eight *nuclei:* two *synergids*, one *egg nucleus*, three *antipodals*, and two *polar nuclei*. They occupy about the relative positions in the embryo sac as shown in Fig. 24.

Pollination.—This is a process in which pollen is transferred from an anther to a stigma. Pollen may be transferred from an anther to the stigma in the same flower. This is termed *autogamy* or *close pollination*. Or, pollen

may be carried from an anther to a stigma of another flower on the same individual plant. This is called *geitonogamy.* Again, pollen may be transferred from an anther to a stigma of a flower on another individual plant. This is termed

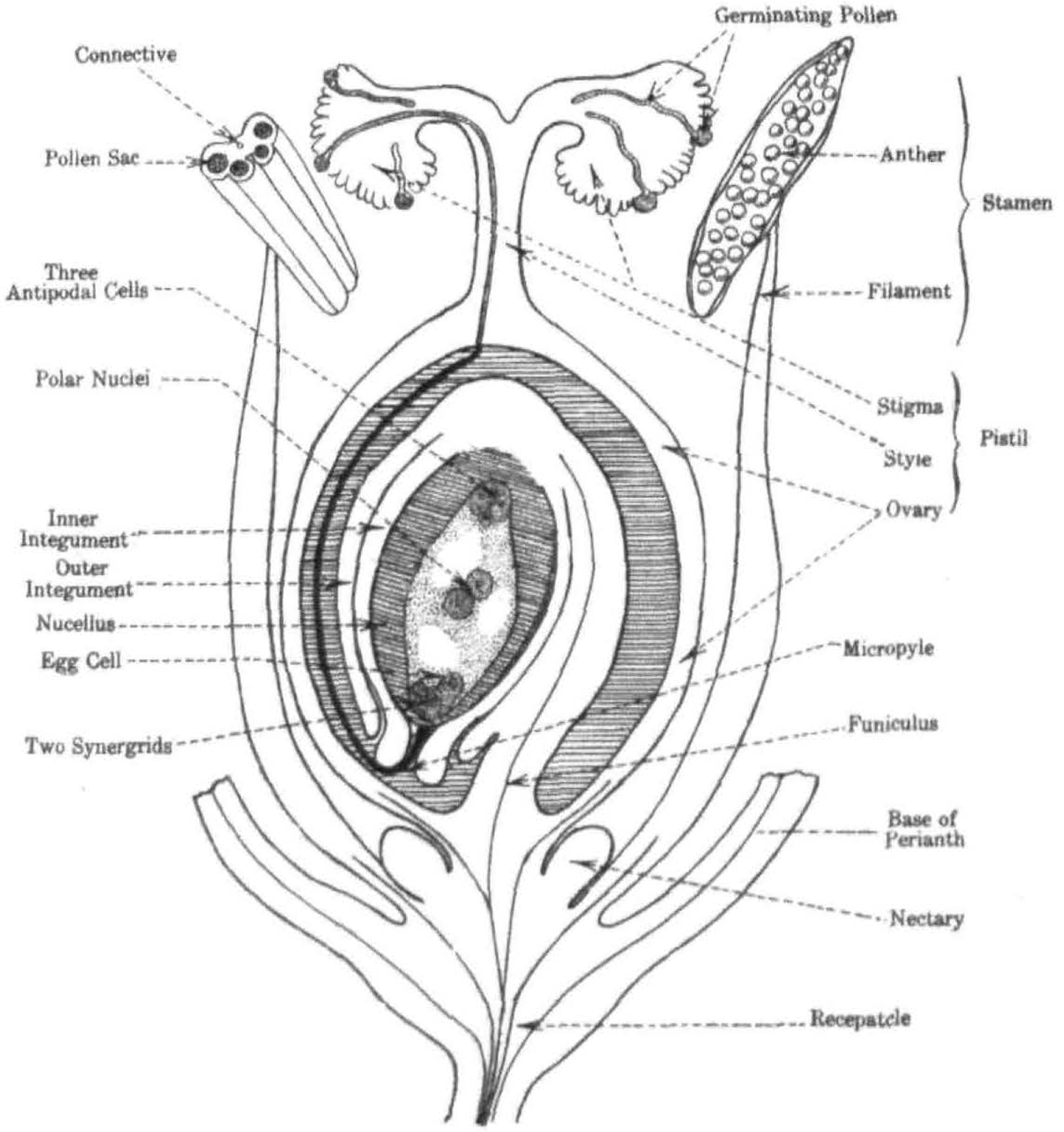


FIG. 24.—The parts of a typical flower in lengthwise section. *(From Holman and Robbins, after Sachs.)*

xenogamy, or *cross-pollination.* Insects, wind and water are the chief agents in the spread of pollen.

Fertilization.—Fig. 24 is a diagram of an ovary with a single ovule cut lengthwise. It shows a stage of development of the ovule about at the time when the pollen grain

has reached the stigma. As has been said, the mature pollen grain consists of a protoplasmic mass surrounded by a rather thick wall. Three nuclei (Fig. 25) constitute the important structures in the pollen grain. It absorbs water and nutrient materials from the stigmatic surface, and grows by sending out a tube, known as the *pollen tube*. The tube grows downward through the stigma, sometimes in a tubular passage, or

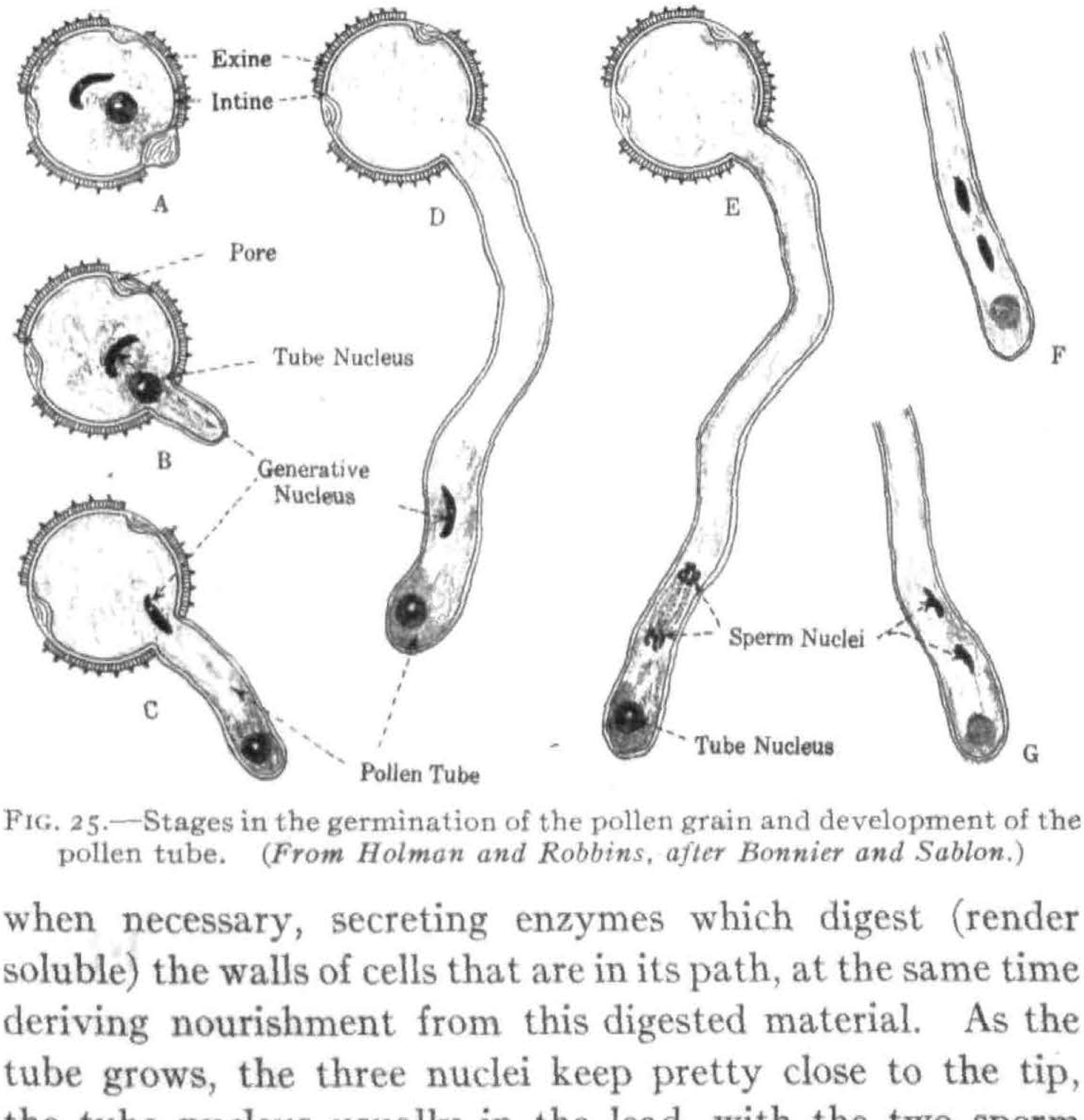


FIG. 25.—Stages in the germination of the pollen grain and development of the pollen tube. (*From Holman and Robbins, after Bonnier and Sablon.*)

when necessary, secreting enzymes which digest (render soluble) the walls of cells that are in its path, at the same time deriving nourishment from this digested material. As the tube grows, the three nuclei keep pretty close to the tip, the tube nucleus usually in the lead, with the two sperm nuclei (male gametes) following. The tube finally reaches the ovule, takes a course through the micropyle and comes into contact with the nucellus. This nucellar tissue is penetrated, and after dissolution of the wall at the tip of the pollen

tube, the three nuclei are discharged into the *embryo sac*. The tube nucleus is reabsorbed. One sperm nucleus unites with the egg nucleus (female gamete) to form the *zygote*, a nuclear mass which contains both the characters of the plant furnishing the pollen (paternal characters) and those of the plant fertilized (maternal characters). The union of the male gamete (sperm nucleus of pollen tube) with female gamete (egg nucleus of embryo sac) is *fertilization*. The fertilized embryo nucleus now develops into a young plant (embryo). The synergids and antipodals are usually disorganized. In grasses and lilies and many other plants, so-called *double fertilization* has been observed. One sperm nucleus has been accounted for, as uniting with the embryo nucleus. The other unites with the two polar nuclei of the embryo sac. The body resulting from this triple fusion also carries both maternal and paternal characters. It grows and develops into the endosperm of the seed. Immediately following fertilization, there is a series of changes not only in the ovule which results in a seed, but in the ovary wall as well.

Just one pollen tube penetrates the embryo sac to bring about fertilization. Many pollen tubes, even hundreds, may penetrate the style, although comparatively few may function normally. Those which do not, wither and die. We may be sure that every ovule that develops into a seed has been visited by one, and only one, pollen tube.

Placentation.—We said that the placenta is the tissue in the ovary to which the one or more ovules are attached. It is traversed by vascular bundles from which branches are given off to the ovules. In currants and gooseberries (Fig. 133) the placentæ are on the ovary wall. Such placentation is said to be *parietal*. In lilies (Fig. 32), the placentation is *axial*, or *central*, that is, the placentæ are on the ovary axis. A third kind of placentation is the *free central*, in

which the ovules are attached to an up-growth of the floral axis in the center of the ovary, which is not connected to the ovary wall by radial partitions.

Symmetry of Flower.—A flower such as the apple, cherry or asparagus can be divided into two approximately symmetrical halves by any diameter (Figs. 160 and 166). Such a flower is said to be *radially symmetrical*, or *actinomorphic*, or *regular*. Contrast this symmetry with that in such flowers as the pea or bean (Fig. 175), in which there is but one plane through which the flower can be divided to separate it into two symmetrical halves. Such a flower is said to be *bilaterally symmetrical*, or *zygomorphic*, or *irregular*.

Relative Positions of Flower Parts.—In the gooseberry or currant flower (Fig. 133), for example, the ovary is below the stamens, corolla, and calyx, and is said to be *inferior*. A flower with an inferior ovary is said to be *epigynous* (above the gynœcium or carpels). When the calyx, corolla, and stamens are inserted on the receptacle below the ovary, the ovary is *superior*, and the flower *hypogynous* (below the gynœcium). The flowers of mustards are hypogynous. There is a third intermediate type of flower, well illustrated by the cherry (Figs. 161 and 167), apple (Fig. 161), etc., in which the petals and stamens are inserted on a calyx rim and arise at about the level of the ovary. In such a case the ovary is *half-inferior* or *half-superior*, and the flower *perigynous* (around the gynœcium).

Union of Flower Parts.—In the primitive flower type, such as the buttercup, the sepals, petals, stamens and carpels are all separate and distinct. A more or less complete union of the parts of each set of floral leaves may take place. For example, in gooseberries and currants, the sepals are united to form a *calyx tube*, in the potato flower the petals are united to form a *corolla tube*, in the cotton flower the stamen filaments are joined, and in many instances—onions, apple,

orange, and others—the carpels are united. The adjectives to describe these various cases are as follows:

	Separate	United
Sepals..........	aposepalous	synsepalous
Petals..........	apopetalous	sympetalous
Stamens........	polydelphous	diadelphous (2 groups) monodelphous (1 group)
Carpels.........	apocarpous	syncarpous

Incomplete Flowers.—The representative flower described in a preceding paragraph had all four floral sets of organs present. However, one or more of these sets may be absent, and in this case, the flower is *incomplete*. Flowers lacking petals are called *apetalous* (buckwheat). When both sepals and petals are absent, the flower is *naked* (willows and cottonwoods). In the majority of flowers, both stamens and pistils, the essential organs of a flower, are present. Such a flower is said to be *perfect* or *hermaphrodite*. Some flowers have but one set of essential organs, either stamens, or a pistil. A flower with stamens only, and no pistil, or a flower cluster (inflorescence) composed of such flowers, is said to be *staminate*. On the other hand, a flower with a pistil but no stamens, or an inflorescence, composed of such flowers, is said to be *pistillate*. If staminate and pistillate inflorescences are on different plants, the species is said to be "*diœcious*." In some diœcious species (hops), the staminate and pistillate inflorescences are very unlike in appearance, while in other diœcious species (salt-grass, *Distichlis*), the two unisexual inflorescences are very similar. If staminate and pistillate inflorescences are on the same individual plant, it is said to be "*monœcious*." This is the case in corn, in which the "tassel" (staminate inflorescence) and the "ear" (pistillate inflorescence) are very dissimilar in appearance.

Inflorescence.—An inflorescence is a flower cluster. Its shape and the arrangement of the flowers in it differ with the

kind of plant. There are three general classes of inflorescences: (1) *simple*, (2) *indeterminate* or *racemose*, and (3) *determinate* or *cymose*.

The simple type is well represented by the calla or tulip, in which one flower terminates the stalk. Mustards and currants have a typical indeterminate or racemose inflorescence. In this, the older flowers are at the base or outside of the flower group and the younger appear in order above them. Moreover, the growth of the inflorescence may continue at the apex. For example, in a cabbage or radish inflorescence, flowers may be opening at the tip, while at the base pods are partially mature. Racemose types of inflorescences are the true *raceme*, *panicle*, *corymb*, *umbel*, *spike*, and *head*. These will be described when they are met with in the family descriptions that follow. The cymose flower cluster is one in which the older flowers are on the inside, and the younger appear in order toward the outside. The length of a flower shoot is determined by the terminal flower. The inflorescence of chickweeds is a cyme.

CHAPTER VII

FRUITS, SEED, AND SEEDLINGS

Development of the Seed.—We have seen how a male nucleus of the pollen tube unites with the egg or embryo (female) nucleus of the embryo sac. The fertilized egg then starts upon a series of divisions, and by growth and development, the young plant or embryo is formed. It may be partially or totally imbedded in the *endosperm*. In some seeds (bean), the endosperm is lacking, and the embryo occupies the entire space within the seed coats. The cells of the nucellus are in part absorbed by the developing embryo, and at most the nucellus is represented by a very thin and compressed layer just within the inner integument. The integuments of the ovule become harder, less permeable, and form the *seed coats*. The *micropyle* is still evident in the mature seed as a small opening.

The embryo or young plant has three main parts: (1) *one or two cotyledons;* (2) the *hypocotyl*, which includes all of the embryo below the cotyledons and terminates in the first root or *radicle;* and (3) the *growing point* of the shoot, upon which are a few leaves, making up a bud.

The parts of a representative mature seed may be summarized as follows:

Seed
- 1. Seed coats.
- 2. Nucellus.
- 3. Endosperm.
- 4. Embryo
  - Growing point of shoot, with leaves (bud).
  - Cotyledon or cotyledons.
  - Hypocotyl, terminating in the young root or radicle.

Development of the Fruit.—The stimulus of fertilization, which is not well understood, extends its influence not only to the ovule, but to the ovary as well. Coincident with the changes resulting in the mature seed, the ovary enlarges, and its walls become changed both physically and chemically. The ovary wall (pericarp) has three distinct layers. Named in order from the outside to the inside, these are the *exocarp*, *mesocarp* and *endocarp*. As the fruit develops the changes that occur in these layers may differ. For example, in the cherry or plum, the exocarp becomes the skin of the fruit, the mesocarp becomes thick and juicy to form the fleshy portion of the fruit, while the endocarp takes on a stony character.

Fruit and Seed Distinguished.—A fruit, botanically, is the matured ovary, with its seeds, and any parts of the flower which may be closely associated with it. The fruit contains the seed or seeds. For example, the entire bean pod is a fruit; the "beans" within are the seeds. It is in the case of dry, one-seeded fruits, particularly, that distinction needs to be made between fruit and seed. For example, the buckwheat fruit (achene) or grass fruit (grain) is commonly called a "seed." But, if development of these is traced and their structure carefully examined, they are seen to be true fruits, with a very thin pericarp (ovary wall) enclosing *one* seed (Figs. 37 and 120).

Kinds of Fruits.—No attempt will be made at this place to give a complete classification of fruits. We will describe the different kinds as we meet with them in the discussions of crop plants. Fruits with a dry pericarp, such as the grain, achene, capsule and pod, are designated *dry fruits*. *Dehiscent dry* fruits (capsule, pod, follicle) split open at maturity in a definite way permitting the seeds to escape. *Indehiscent dry* fruits (achene, grain) do not split open at maturity in any definite way. Fruits with a fleshy pericarp, such as the berry, are called *fleshy fruits*.

Germination of Seed.—The seed must have an adequate supply of water, oxygen and heat in order to germinate. The initiatory stages in germination are the absorption of water and the secretion of enzymes in the seed, which render soluble the stored food material necessary to nourish the growing embryo. This food may be stored in the endosperm, as in all grains, or in the cotyledons, as in beans and peas. The embryo is dependent upon stored food for its initial growth. The swelling of the seed, due to water absorption and growth of the embryo, ruptures the seed coats, and the young shoot and primary root make their appearance. The cotyledons are brought above ground in some plants (beans, squashes, etc.) and constitute the *temporary* or *seed leaves*. They may develop chlorophyll and make food for a while. The true foliage leaves develop, partly at the expense of the food stored in the cotyledons, which gradually dwindle away. In many plants, *e.g.*, all grasses, the cotyledon remains in the soil. In these the first leaves are true foliage leaves.

As soon as the first roots are established, making it possible for the plant to absorb water and mineral nutrients from the soil, and a few leaves are formed, the young plant is capable of making its own food and living an independent life. It has been tided through its early stages of development by food stored in the seed. Generally speaking, large seeds of any given species produce more vigorous seedlings than small ones, and this is probably correlated with a greater abundance of stored food in the former.

CHAPTER VIII

THE CLASSIFICATION AND NAMING OF PLANTS

That subject which deals with the arrangement of plants into groups, based upon their structure and form, is designated *Systematic Botany*. From the earliest times, man has attempted to classify the large and varied assemblage of plants which he has found on the earth. There have been many systems of classification, some "artificial," some "natural." An artificial system of grouping plants may use purely arbitrary bases; it may be convenient, but fail to express the natural affinities of plants. For example, in an artificial system, we might choose to put all those plants with red flowers into one group, and those with blue flowers into another class, and so on, thus basing our classification on flower color. Or, we might put trees into one group, shrubs into another, and herbs into still another, thus basing the grouping on size and growth habit. Obviously, we would throw together plants which have no natural relationships, and in some cases, separate those which are naturally allied. An artificial system would not take into account the evolutionary tendencies in the plant world. It is agreed that one system of classification is better than another if it more accurately expresses the natural affinities and the evolutionary tendencies of the organisms dealt with.

In the early history of systematic botany, the systems of classification were largely artificial. As the knowledge of plants increased, one system supplanted another, and in most cases was an improvement over the old one. One of the first natural systems of classifying plants (and animals)

was that of Linnaeus. The first edition of his notable work, Systema Naturæ, was published in 1735. There follow the systems of De Jussieu (1789), De Candolle (1819), Eichler (1883), Bentham and Hooker (1826–1883), and Engler and Prantl (1890–1896). Two recent systems are those of Bessey (1907), and of Schaffner (1911).

Reproductive versus Vegetative Organs in Classification. In all higher plants, reproductive and vegetative organs differ markedly from each other. Reproductive tissues are less influenced by environmental conditions than are vegetative tissues. There may be little resemblance between the vegetative portions of two species, although their reproductive structures may be very similar. For example, the strawberry and raspberry have quite different growth form, and their vegetative organs are quite dissimilar, yet the flowers of the two are constructed on the same general plan. On the other hand, two plants with very dissimilar reproductive structures, *i.e.*, having little natural relationship, may resemble each other very closely in their general vegetative appearance. These conditions show that, although vegetative structures may be modified to a great degree under diverse environmental influences, these same influences do not modify, to an equal extent, the reproductive organs. Hence, on account of this greater stability of the reproductive structures of a plant, these are of relatively great value in showing actual relationships, and are of prime importance in classification.

GROUPS OF PLANTS

A survey of the plant kingdom shows it to be composed of a great variety of plants, differing in size, in structure, in habitat, and in method of living.

The "thallus plants" (Thallophytes) include the simplest organisms. This group is divided into two large subdivi-

sions, the *Algæ* and *Fungi*. The Algæ include the green scums so frequently observed upon the surface of pools, stagnant ponds, reservoirs, ditches and streams. They are also commonly found in tanks and water troughs, and, in such places may render the water objectionable to stock, especially when decay sets in. The brown and red "sea weeds" are also Algæ. The Fungi are a large group of plants, probably the best known being the bacteria, the molds of bread, fruit, and cheese, the rusts and smuts of the cereals, the toadstools and mushrooms, the mildews, and the fungi causing such well-known diseases as blight of potato, alfalfa leaf spot, apple scab, wilt of cucurbit, etc.

The "moss plants" (Bryophytes) include the liverworts, peat mosses, black mosses, and common mosses. They are a group of comparatively slight economic importance.

The "fern plants" (Pteridophytes) are represented by the true ferns, and closely allied plants such as the horsetails or scouring rushes, and club mosses. Like the preceding groups, fern plants do not produce seed but reproduce in a much simpler fashion, by spores.

The highest and most complex group is the "seed plants" (Spermatophytes). It includes the *Gymnospermæ* (pines, spruces, firs, hemlocks, cedars, junipers and other cone-bearing plants) and the *Angiospermæ* (higher seed plants or flowering plants). All the common crop plants, of field, orchard, and garden belong to the Angiospermæ. In the Gymnospermæ the seeds are exposed, while in Angiospermæ they are enclosed in a case, the ovary wall. Angiospermous plants fall into two groups (subclasses): (1) *Monocotyledones*, in which the seeds have one cotyledon, the flower parts are in threes, the leaves are parallel-veined, and the vascular bundles are scattered throughout the pith (examples: cereals, onions, asparagus, lilies); (2) *Dicotyledones*, in which the seeds have two cotyledons, the flower parts are in fours or fives, the

leaves are netted-veined, and the vascular bundles are in the form of a cylinder about the pith (examples: buckwheat, beet, apple, cherry, mustard, cotton, melon, potato).

Each of these subclasses is further subdivided. A complete classification of some plant, *e.g.*, common alfalfa, will give the principal subdivisions:

Spermatophyta,
  Angiospermæ,
    Dicotyledones,
      Order Rosales,
        Family Leguminosæ,
          Genus Medicago,
            Species Medicago sativa.

The order ending is usually "*ales*." Orders are subdivided into families. The family ending is commonly "*aceæ*" or "*æ*." Families are split up into *genera*, and genera into *species*. The number of families, genera, and species may be large or small.

THE PLANT KINGDOM

Thallophyta—"Thallus plants."

Sub-division 1.—Algæ.

Class 1—Cyanophyceæ—blue-green algæ.
Class 2—Chlorophyceæ—green algæ.
Class 3—Phæophyceæ—brown algæ.
Class 4—Rhodophyceæ—red algæ.

Sub-division 2.—Fungi.

Class 1—Bacteria.
Class 2—Myxomycetes—slime fungi.
Class 3—Phycomycetes—algal fungi.
Class 4—Ascomycetes—sac fungi.
Class 5—Basidiomycetes—club fungi.

Bryophyta—"*Moss plants.*"

Class 1—Hepaticæ—liverworts.

Class 2—Musci—mosses.

Pteridophyta—"*Fern plants.*"

Class 1—Filicineæ—true ferns.

Class 2—Equisetineæ—horsetails.

Class 3—Lycopodineæ—club mosses and related plants.

Spermatophyta—"*Seed plants.*"

Class 1—Gymnospermæ—conifers and related plants.

Class 2—Angiospermæ—higher flowering plants.

Sub-class 1—Dicotyledones—dicotyledons.

Sub-class 2—Monocotyledones—monocotyledons.

PLANT NOMENCLATURE

Scientific Name.—The system of nomenclature in use by all biologists today is the so-called *binomial system*. In this, the scientific name of each plant (and animal) is composed of two words. For example, the scientific name of the common garden bean is *Phaseolus vulgaris* L. The first word, *Phaseolas*, is the name of the *genus* (pl. genera), or *generic* name; the second, *vulgaris*, is the name of the *species* (pl. species) or *specific* name. The letter "L" following the scientific name of the common garden bean is the abbreviation for Linnaeus. Placed in this position after the name of the plant, it signifies that this species was first named and described by Linnaeus. This description may be found in published form. It is the practice of those engaged in the systematic study of plants and animals to record accurately the description, in some recognized scientific periodical, or in a monograph, of any new species they may find. When such is done, the one who names and describes the new plant affixes thereto his name, in full, if short, but usually abbreviated. In some instances, two abbreviations occur after a scientific name, for

example, *Echinochloa crus-galli* (L.) Beauv. This illustrates a case in which a species has been transferred from one genus to another. Linnaeus named the common barnyard grass *Panicum crus-galli* L. In his revision, Beauvois transferred the common barnyard grass to the genus *Echinochloa* still retaining the specific name, *crus-galli*. Nomenclature rules state that when a species is transferred in this manner from one genus to another, the original author (in this case, Linnaeus) must always be cited in parenthesis, followed by the author (in this case, Beauvois) of the new binomial.

Botanical varieties or subspecies are often printed as trinomials, for example, the bush variety of *Phaseolus vulgaris* is written *Phaseolus vulgaris nanus* or *Phaseolus vulgaris var. nanus*. Agricultural "varieties" are designated by common names, for example, in beans, there are such varietal names as Early Bountiful, Black Valentine, Giant Stringless, Green-pod, etc.

Scientific names are in Latin. This is probably the most universal language, which fact was recognized by Linnaeus, and hence he adopted it in his system of nomenclature. The species and genus agree in gender. For example, *Brassica rapa* (turnip), *Triticum aestivum* (common wheat), and *Rubus villosus* (northern dewberry).

Descriptive Nature of Specific Names.—Specific names are commonly descriptive. They may be descriptive of (1) some plant character or habit, (2) habitat, or (3) distribution; and, in some instances (4) the species may bear the name of an individual. By far the largest proportion of specific names is descriptive of some striking habit or character of the plant. For example, the trailing or procumbent *Trifolium* (clover) is *Trifolium repens* (*repens*, creeping); the sweet clover with white flowers is *Melilotus alba* (*alba*, white); the narrow-leafed crab-apple is *Malus angustifolia* (*angustus*, narrow—*folium*, leaf).

In *Vitis riparia*, the streamside grape, *riparia* is descriptive of this species' habitat. The common black-cap raspberry is *Rubus occidentalis;* here the specific name means "western." Again, in *Vaccinium canadense*, the Canada blueberry, the specific name indicates geographical distribution. The systematist frequently uses the name of an individual for the specific name. This may be done as a token of friendship, or recognition of distinction, or to indicate the finder of the new form. For example, *Prunus besseyi*, is after the well-known botanist, Charles Bessey. The *i* ending is the Latin genitive, signifying "of Bessey."

Scientific Name versus Common Name.—There are distinct advantages connected with the knowledge and use of scientific names. Often the same species has many common names. Again, several distinct species often may go by the same common name. The use of one scientific name will do away with much misunderstanding as to what plant is actually referred to.

General References

BAILEY, L. H.: The Standard Cyclopedia of Horticulture. The Macmillan Co., 1914.

BAILLON, H.: Histoire des plantes. Paris, 1894.

BENTHAM, G., and HOOKER, J. D.: Genera Plantarum. London, 1862–1883.

BRITTON and BROWN: An Illustrated Flora of the Northern States and Canada. Scribners, New York, 1913.

CARD, FRED W.: Bush-fruits. The Macmillan Co., 1909.

CORBETT, L. C.: Garden Farming. Ginn & Co., 1913.

COULTER, J. M., BARNES, C. R., and COWLES, H. C.: A Textbook of Botany. American Book Co., 1911.

DE CANDOLLE, ALPHONSE: The Origin of Cultivated Plants. D. Appleton & Co., 1892.

ENGLER and PRANTL: Die natürlichen Pflanzenfamilien.

HEDRICK, W. P.: Sturtevant's Notes on Edible Plant's. N. Y. Agr. Exp. Sta. 27th Ann. Rept. Vol. 2, Pt. 2, 1919.

HOLMAN, R. M., and ROBBINS, W. W.: A Textbook of General Botany. John Wiley & Sons, Inc., 1924.

HUNT, T. F.: Forage and Fiber Crops in America. Orange Judd Co., 1908.

KNUTH, PAUL: Handbook of Flower Pollination. Translation by J. R. Ainsworth Davis. Oxford Clarendon Press, 1906.

MONTGOMERY, E. G.: Productive Farm Crops. Lippincott Co., 1916.
PERCIVAL, JOHN: Agricultural Botany. Henry Holt & Co., 1905.
PIPER, CHARLES V.: Forage Plants and Their Culture. The Macmillan Co., 1914.
SHEPPERD, J. H.: Root Systems of Field Crops. N. D. Agr. Exp. Sta. Bull. 64: 525–536, 1905.
STRASBURGER, E., NOLL, F., SCHENCK, H., and SCHIMPER, A. F. W.: A Textbook of Botany. Macmillan Co., 1912.
TEN EYCK, A. M.: The Roots of Plants. Kans. Agr. Exp. Sta. Bull. 127: 199–252, 1904.
VILMORIN, M. M.: The Vegetable Garden. John Murray, London, 1905.
WEAVER, JOHN E., JEAN, F. C., and CRIST, J. W.: Development and Activities of Roots of Crop Plants. Carnegie Inst. of Wash. Pub. 316: 1–117, 1922.
WOSSIDLO, PAUL: Leitfaden der Botanik. Berlin, 1911.

PART II

CHAPTER IX

GRAMINEÆ (POACEÆ), GRASS FAMILY

No family of plants is of greater economic importance than the grass family. It has several thousand species, among which are the "grains" such as wheat, oats, barley, corn, rice, and others) and the meadow, pasture and range grasses. The grasses grown for "grain" were the first plants to be cultivated by the human race. Members of this family are widely distributed over the surface of the earth, from tropical to polar regions and from low to very high altitudes. In many parts of the world, grasses form a dominant part of the plant covering. Examples of extensive grass associations are meadows, steppes, and savannahs. Meadows are moist grass lands and may occur in all climates. Steppes are dry grass lands. The Old World steppes of Russia, Hungary, Roumania, and Spain, the plains of the Western United States, and the pampas of South America are excellent examples. Savannahs are dry grass lands with scattered trees. The best examples of these are the llanos of Venezuela, and the patanas of Ceylon.

Most grasses are low, erect herbs. A few, such as the bamboos, are shrubs or trees. Bamboo has a woody stem which may reach a height of 100 feet or more. Some grasses are trailing, one or more being reported as climbing over trees 100 feet high. Others, like rice cut grass (*Homalocenchrus*) are feeble climbers or support themselves by means of numerous hooked prickles on their leaves.

Many of our common pasture and meadow grasses, and all the cereals, complete their life period in one season. Such plants are said to be *annual*. In cool climates, certain grasses behave as winter annuals, living through the winter as small plants and sending up flower stalks the following spring. So-called "winter" or "fall grasses" behave in this manner. A number of grasses, such as the pernicious quack grass (*Agropyron repens*), lawn grass (*Poa pratensis*), and others, are *perennial*, *i.e.*, with a course of life extending over three or more seasons.

Roots.—The root system of grasses is *fibrous*, that is, composed of numerous slender roots of about equal diameter. No grasses, at maturity, possess a tap-root system, as that of radish, dandelion, beet, and others. In this there is a strong leading central root. The primary roots, those that arise directly from the seed, are temporary, dying after the permanent roots are able to support the plant. The permanent roots arise from that portion of the stem which extends from the germinating seed to the surface of the ground. These roots are always produced at about the same distance below the surface, regardless of the depth at which the seed is planted (Fig. 4).

Grasses are classed as shallow-rooted plants. However, great variation has been observed in the depth to which the roots penetrate, some extending to depths which cannot be considered as shallow. Roots of buffalo grass (*Buchloe*) sometimes go to a depth of 7 feet. Rye roots have been found penetrating to a depth of 6 feet, corn 7 feet (Fig. 59), and wheat more than 6 feet.

Roots may break through the sheaths (that part of the leaf which is wrapped about the stem) of the first few leaves, or spring freely from underground stems. They may also arise from joints above the ground line, as in corn. If such aerial roots reach the ground they may serve as supporting or "prop" roots.

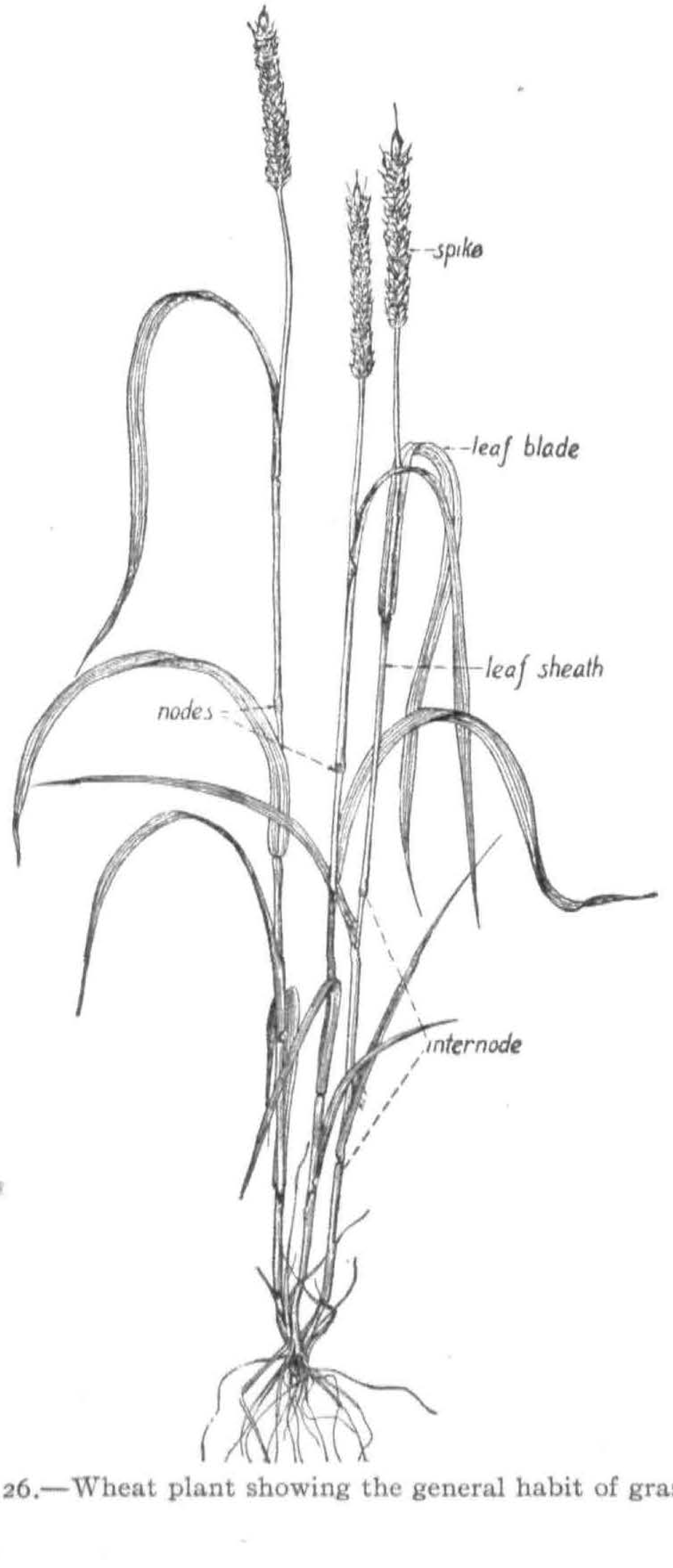


FIG. 26.—Wheat plant showing the general habit of grasses.

Stems.—*General Characteristics.*—The stems of grasses are called *culms*. They are cylindrical (rarely flattened), and divided into sections (*internodes*) (Fig. 26) which are usually hollow, but sometimes filled with pith, as in corn. When young, the internodes are solid, but, as the stem enlarges, the central portion is ruptured and a hollow is formed. The *nodes* (Fig. 26), the enlarged joints between the internodes, are solid. Enlargement of the nodes is due partly to a thickening of the leaf base at each node (Fig. 27) and partly to enlargement of the stem itself. In most grasses, the part of the culm within the sheath remains soft and continues to grow or retain the power of growth after the portion not in the sheath has ceased growth, or lost the ability to grow. The youngest part of each internode is at its base, surrounded by the basal swelling of the leaf sheath (Fig. 27). Each internode has its own growing zone.

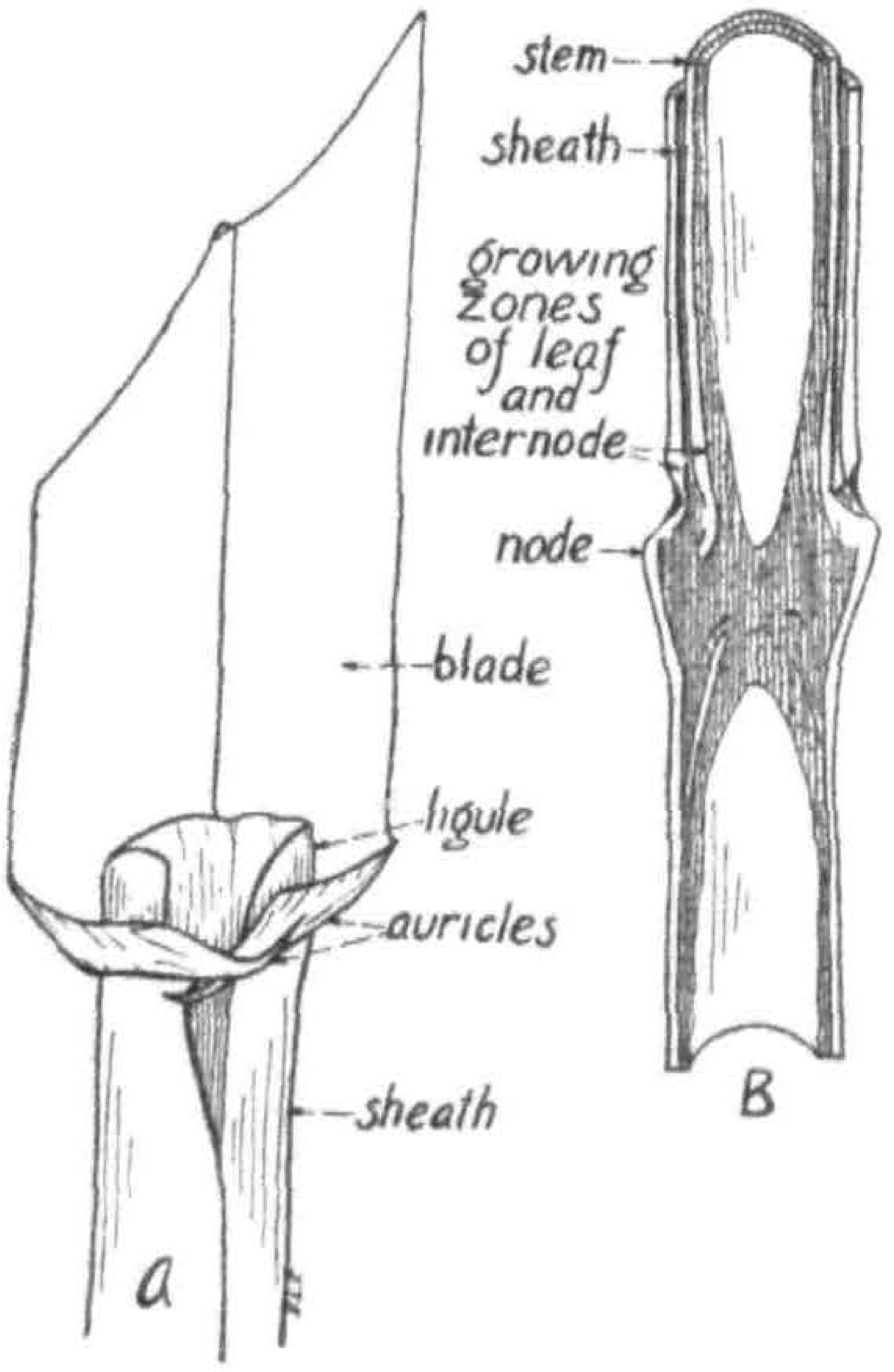


FIG. 27.—Barley. *A*, portion of leaf at juncture of leaf and blade; *B*, stem cut in median lengthwise section. × 2½.

Lodging.—It is customary to speak of a grass as "lodged" when its stems are bent over and caused to lie on the ground by the mechanical action of a high wind, or driving rain. Some grasses lodge more easily than others. This may be due either to their greater height, heavier fruiting head, to a lack of strengthening material in the straw or to a weakness of the roots.

In many spring wheats, the adventitious root system descends almost vertically, the individual roots are not highly lignified, and as a result the roots do not have a strong hold on the soil, and are quite easily bent over. Moreover, it has been shown that an excessive amount of available nitrates in the soil favors lodging. As it has been demonstrated that the application of nitrate fertilizers to a soil tends to suppress the amount of silicon taken in by the wheat plant, the greater frequency of lodging of plants grown on such a soil has been thought by some to result from a stem weakness caused by a lack of silicon within them. However, it has been demonstrated that the straw of lodged wheat is as rich in silica as that of standing wheat.

The stems of lodged grain are not necessarily broken. The reverse is the case, as is shown by the fact that the lodged culm has the power of partially or entirely erecting itself. This power is exhibited more strongly in growing or immature culms than in old ones. When a grass stem is lodged, the cells on the lower side of each internode, at its base, grow more rapidly than those on the upper side, and, hence, the stem curves upward. This behavior is a response to the stimulus gravity. The manner in which gravity as a stimulus acts upon an organ has not been demonstrated. However, it has been experimentally determined that all plants make pronounced adjustments in their growth in response to gravitation. This property is called *geotropism*.

Tillering.—It is a common observation that trees, shrubs and most herbaceous plants produce side branches in regular order, and that these arise at the nodes along the stem. The side branches of the grasses are not so obvious as those in trees and shrubs, for example, for the reason that the culms of most grasses produce branches from the lower nodes only. This branching in grasses is known as "stooling," "tillering," or "mooting." The individual branches are known as

"tillers" (Fig. 28), and the entire mass of branches is the "stool." Common cereals, such as wheat and oats, invariably produced a number of tillers, sometimes as many as 50. The tillers from the primary culm may produce tillers (lateral branches) and these in turn other tillers, so that under favorable conditions several dozen culms may result from a single seed. As the internodes are much shortened, the branches

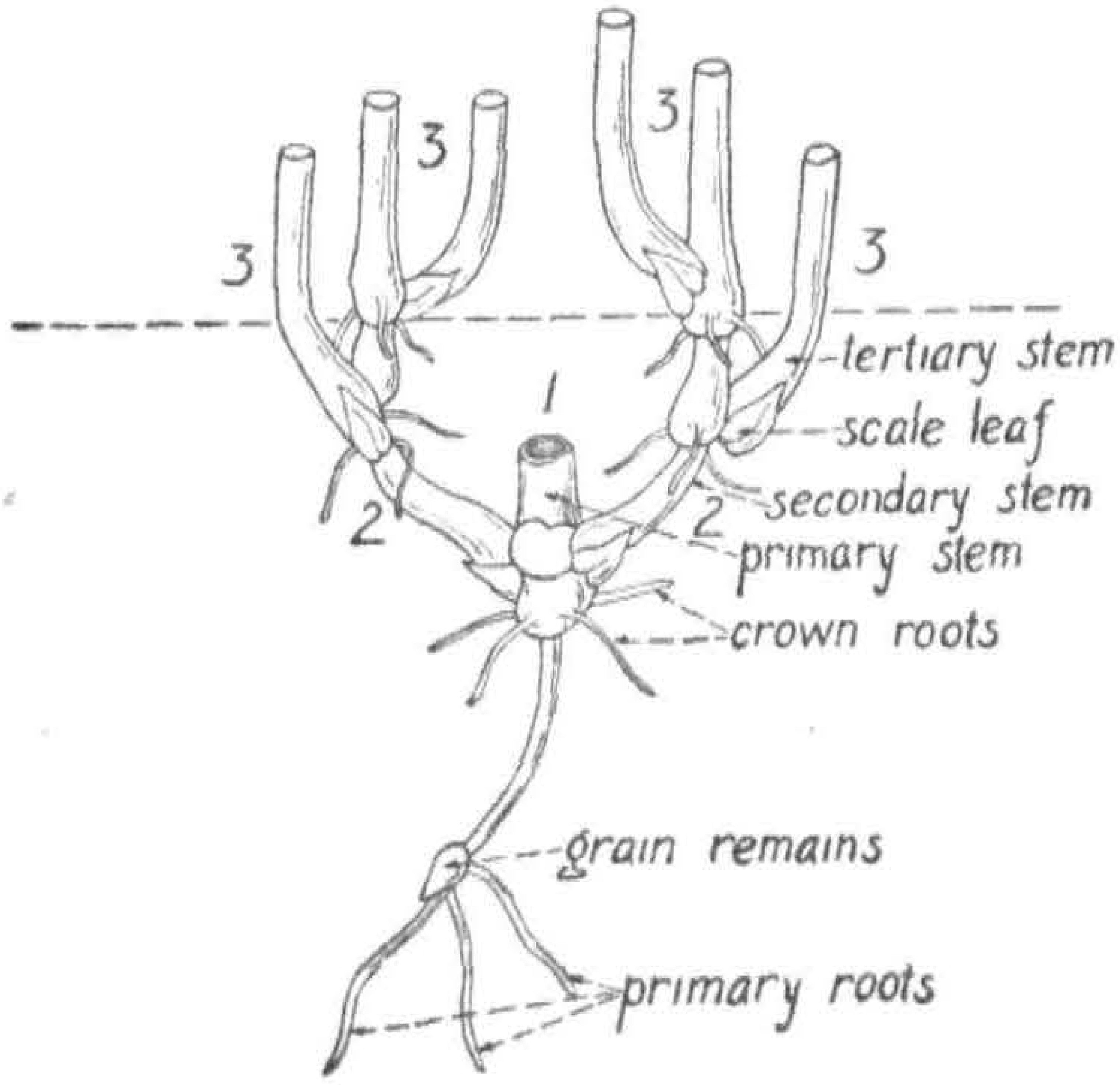


FIG. 28.—Diagrammatic representation of tillering in cereals. (*After Schindler.*)

appear to come out at one point. In the wheat plant, two or three weeks old, three or four buds may be found, one in the axil of each leaf. Tillering results from the outgrowth of these lateral buds.

Tillering activity varies with the species, the individual, and environmental conditions. In general, winter grains tiller more than summer ones. It is dependent especially upon the depth of seeding. It has been shown that bearded varieties have a greater capacity for tillering than beardless varieties; that the number of tillers per plant is less when close seeding is practiced, than when plants are not crowded;

however, close seeding results in earlier maturity and better quality of kernel than wide seeding. The number of tillers per plant is increased by early seeding. Tillering is stimulated by nitrogen and phosphoric acid; potash has little effect. There seems to be an optimum depth, which varies with the sort of grass. The average depth of the tillering node in cereals is about 1 to 2 centimeters, regardless of the depth at which the seed has been planted. In wheat, when seed is planted deep, the epicotyl lengthens to form a thin "rhizome" which lifts the plumule upward to within about 1 or 2 centimeters of the surface, at which level, tillers begin to form. In case the seed is planted at a depth of four or more inches, the epicotyl must lengthen considerably to bring the plumule to the tillering point, and in this event, the epicotyl may consist of several internodes. Tillers are produced freely in moderately warm, sandy soil. The number of tillers is also increased by a large amount of reserve material in the seed, and by high soil fertility, and by thin seeding. The effect of this last factor is well shown in the following data taken from the Nebraska Experiment Station Bulletin 127:

TILLERING OF OATS

Pecks of seed sown per acre	Stems per 100 plants	Total number of stems per acre
4	466	1,419,000
8	279	1,732,000
16	140	2,283,000

The production of tillers in the small grains is altogether desirable from the farmer's standpoint, as it is an important factor determining yield.

Bulbous Grasses.—In a few species such as timothy (*Phleum pratense*) and tall oat grass (*Arrhenatherum elatius*),

some of the lower, short internodes are enlarged into bulb-like bodies containing a store of nourishment.

Rhizome-bearing Grasses.—Perennial grasses usually have *rhizomes* or *rootstocks,* horizontally elongated underground stems, which give rise to erect annual stems that bear foliage leaves and flowers. These underground stems are very efficient as reproductive organs, for, as a result of their elongation in the soil, the plant is able to invade areas already occupied by other plants. Furthermore, each rootstock is capable of budding a new plant at every node, and should it be dragged from the ground by cultivating machinery and broken into a number of separate pieces, each piece will give rise, under favorable conditions, to a new plant. Quack grass (*Agropyron repens*), and many other of our worst weeds, owe their obnoxious character mainly to the possession of rootstocks. Such plants are not dependent upon seed production alone, but in addition spread by means of their rootstocks. The rootstock is a storehouse of food material, and although the leaves and stems above ground may be destroyed, new shoots are sent up from it, drawing upon the stored food supply. For this reason, perennial weeds of all kinds are difficult to eradicate. Any method of elimination adopted is based upon the knowledge that the food stored in the underground stems is made in the green leaves; therefore, the development of green leaves must not be allowed.

Rhizomes of grasses bear brown or colorless sheathing scales (rudimentary leaves) containing in their axils active buds which may develop into erect stems. Under favorable conditions, roots are produced at the nodes of the rhizomes. Grasses possessing rhizomes are said to be *rhizomatous.*

When the internodes of the rhizomes are very short, the culms are close together, and the grass is known as a *tufted grass* or as *bunch grass,* as in meadow fescue (*Festuca pra-*

tensis). Many of our most valued range grasses have the bunch habit. When the internodes are long, the culms are more widely separated, and a creeping grass, as awnless brome grass (*Bromus inermis*), is the result.

Stoloniferous Grasses.—When the horizontal stems are at or above the surface of the ground, they are called *runners* or *stolons*, as in buffalo grass (*Buchloe dactyloides*). Outside of the grass family, the runners or stolons of strawberry are very typical. Stolons are about as effective as rhizomes in propagation. They usually produce a more open, loose tuft. This is due to the long internodes. Stoloniferous grasses do not produce as solid and uniform a turf as most rhizomatous grasses. Neither is it likely that the former would produce a sod that would be as enduring under conditions affecting the sod surface, such as heavy trampling or close grazing.

Leaves.—*General Characteristics.*—In grasses, a single leaf arises at each node. Leaves disposed in this fashion along a stem are said to be *alternate.* If one starts with a certain leaf, the leaf next above or next below, is on the opposite side of the stem, 180° around the circumference. This arrangement gives two vertical rows of leaves opposite each other on the stem. Such an arrangement is said to be *two-ranked, distichous*, or *one-half spiral*. We shall have occasion further on to discuss other leaf arrangements.

The grass leaf in general appearance is unlike that of such common plants as apple, cottonwood, maple and beet. In these the leaf has a definite, narrow stalk or petiole and an expanded blade. The grass leaf is divided into two distinct parts, *sheath* and *blade* (Fig. 27). The sheath represents the leaf base, and forms a tube around the culm. At the base of the leaf sheath, there is a distinct swelling. The more or less flattened part of the leaf which spreads away from the culm is the *blade* (lamina). The blades are parallel-veined, that is, have many veins, about equal

in size, running parallel, and joined by inconspicuous veinlets. Parallel venation is characteristic of the leaves of grasses, sedges, rushes, lilies and most all other monocotyledonous plants.

Growth of Leaves.—In the early life of the grass plant, leaves grow faster than internodes. This results in a tuft of leaves. Some leaves elongate indefinitely. The tip of the leaf blade is the oldest portion. The growing point is at the base of the blade. This growing zone, as a rule, is marked by a whitish or light green semicircle (Fig. 27). The upper portion of the leaf may therefore be removed without permanent injury to the plant. This is well shown in the rapid recovery of the leaves of lawn grass after mowing, and of pasture grasses after grazing.

Scales and Bracts.—Reduced leaves in the form of scales and bracts occur in grasses. Such reduced leaves are termed "*scales*" when they appear lower on the stem than the foliage leaves, and "*bracts*" when higher. For example, the reduced leaves at tillering nodes are "scales" (Fig. 28), while the reduced leaves (glumes) in the inflorescence are "bracts" (Fig. 29). Scales and bracts seldom possess chlorophyll (green coloring material in plants), and, hence, are incapable of carrying on synthesis of carbohydrates. The scales and bracts in grasses have the same one-half spiral arrangement as the foliage leaves and although they may be very close together on the axis, careful observation shows them to have this typical arrangement of all grass leaves.

Ligule.—At the junction of the sheath and blade is a membranous or cartilaginous ring or fringe, the *ligule* (Fig. 27). It is next to the culm, and varies in size, shape, and hairiness in different species of grasses. The ligule is sometimes absent.

Auricle (Fig. 27).—This is a more or less pointed, thin, ear-like structure projecting from the leaf edge at the junc-

tion of sheath and blade. It often clasps the stem but may be more or less twisted and bent away from it. It varies greatly in size and shape. They are entirely absent in some species.

Inflorescence.—The grass inflorescence (flower cluster) consists of a number of groups of flowers, each group being called a *spikelet*. The spikelet is, in fact, the unit of the grass inflorescence. The spikelets are attached either directly or indirectly to a main axis, the *rachis* (Fig. 29).

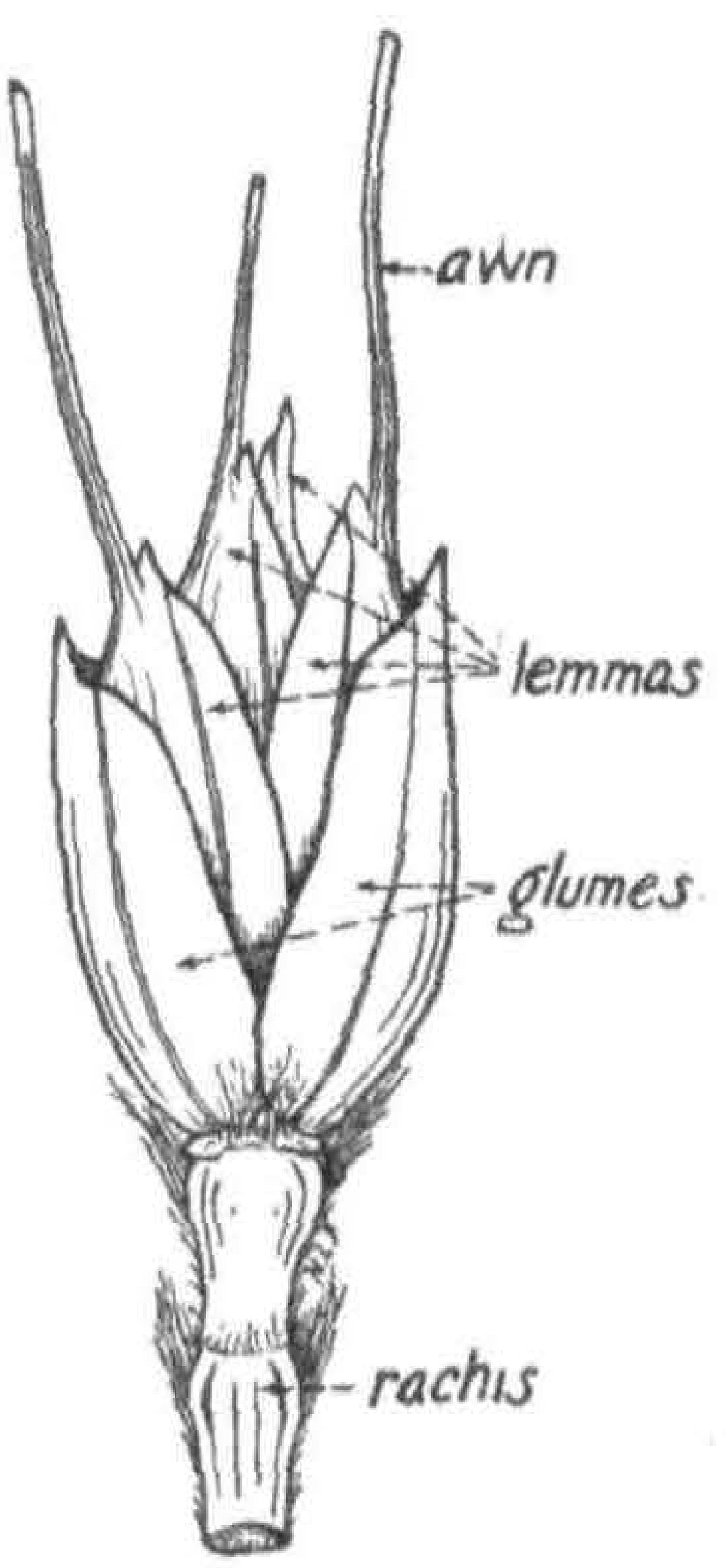


FIG. 29.—Single spikelet of common wheat (Triticum æstivum). × 2.

The three common sorts of grass inflorescences are the spike, panicle, and raceme. When the rachis is unbranched, so that the spikelets are not borne on individual stalks, but are attached directly (sessile) to the rachis, the result is a *spike*. The inflorescences of wheat, barley, and rye are good examples of spikes. Usually, each culm bears a single spike. In the *raceme*, each spikelet is borne on a short branch of the rachis, as in sheep's fescue (*Festuca ovina*). In the *panicle*, primary branches of the rachis branch one or more times (Fig. 47). These branches may be long and widely spreading, as in oats and brome grass, or short and rather appressed to the rachis, as in timothy, meadow foxtail (*Alopecurus*), and *Koeleria*.

Spikelet.—The spikelet is the unit of inflorescence in grasses. A typical spikelet, such as that of oats (Fig. 49), or wheat (Fig. 29), for example, consists of a shortened axis, the *rachilla*, bearing a number of chaff-like, two-ranked (distichous), overlapping bracts (glumes of some authors). The two lowermost bracts are empty, that is, do not bear

flowers in their axils. Fig. 30 shows a dissected wheat spikelet with its parts removed in order. Each spikelet is subtended by these two empty bracts. Following the suggestion of Piper, we shall designate these two basal, empty bracts as "*glumes*." The lower of these is the "first glume," the upper the "second glume." Above the two glumes, on the rachilla, are one or more bracts; each one of these is known as a *lemma* (flowering glume and inferior palea of some authors). Normally, there is a flower in the axil of each lemma. Opposite each lemma is a two-nerved, two-keeled, bract-like structure, the *palet* (the palea, prophyllum,

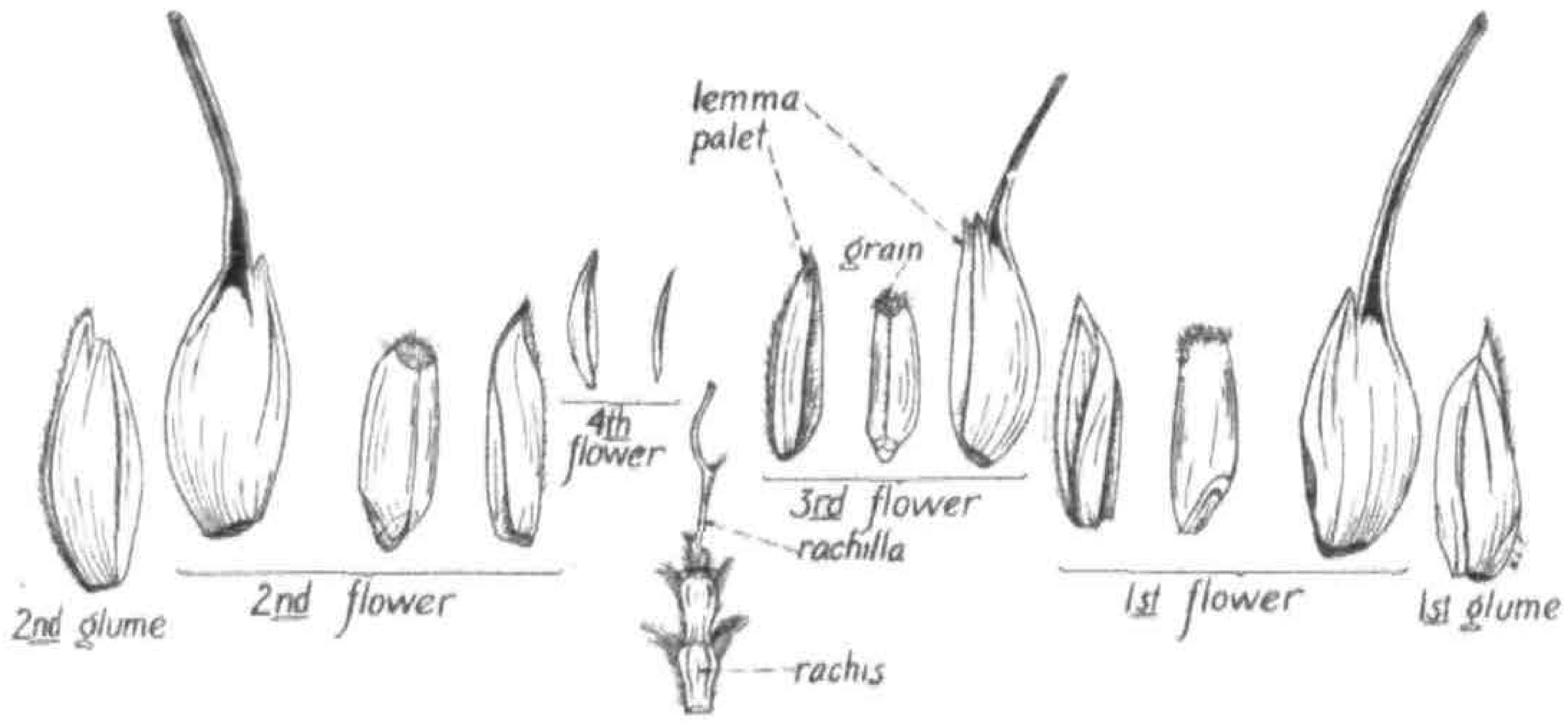


FIG. 30.—Spikelet of common wheat (Triticum æstivum) dissected, the parts removed in order.

bracteole, and superior palea of some authors). Its back is turned toward the rachilla. It frequently envelops the other parts of the flower with its infolded edges. The palet is never awned (bearded). While the glumes and lemmas are inserted on the rachilla, the palet is inserted on a very short flower stalk (pedicel). At the base of the ovary, on the side opposite the palet, are two minute scales, the (anterior) *lodicules* (Fig. 31). Inside the palet, and placed farther up on the flower stalk, are three *stamens* and a single *pistil*. Thus we see that in the typical spikelet there are two glumes subtending one or more lemmas; in the axil of each lemma is

a flower, and each flower consists of a palet (outer perianth), two lodicules (inner perianth), three stamens, and a single pistil. Each stamen has a large anther. The filament (*stalk*) is attached at the base of the anther, but on account

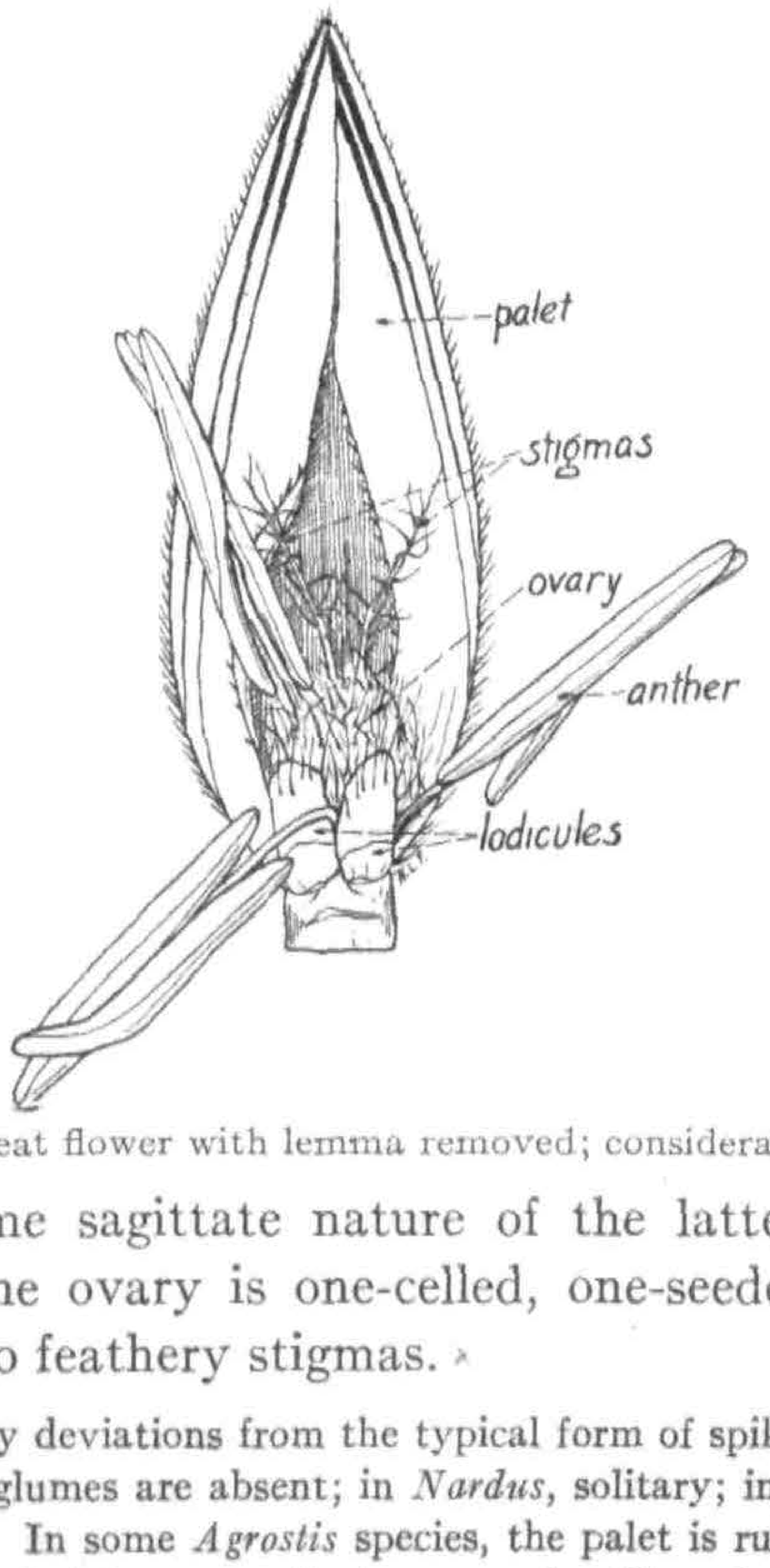


FIG. 31.—Wheat flower with lemma removed; considerably magnified.

of the extreme sagittate nature of the latter, it appears versatile. The ovary is one-celled, one-seeded, bears two styles and two feathery stigmas.

There are many deviations from the typical form of spikelet. In *Coleanthus*, the empty glumes are absent; in *Nardus*, solitary; in *Homalocenchrus*, mere rudiments. In some *Agrostis* species, the palet is rudimentary. It is not always two-keeled, but generally two-nerved. There is a third (posterior) lodicule in some grasses. Although the stamens are as a rule three, there are six in most bamboos and in rice (*Oryza*). In *Streptochæta* and *Oryza* (occasionally), there are three styles, and only one in *Nardus*.

The *awns* or *beards* are brittle-like structures on lemmas or glumes, usually on the former. They are commonly terminal, as in wheat, or dorsal (attached to back of lemma), as

in oats. There is evidence that awns are transpiring (water-losing) organs. It has been noted that bearded barley spikelets transpire more than artificially beardless ones of the same sort under similar conditions. It has also been observed that, at the time of kernel development, transpiration from the spikelet is most intense, probably corresponding to the time of greatest movement of reserve material to the kernel.

Many species of cleistogamous grasses have been reported. As compared with flowers that open, cleistogamous ones generally have reduced lodicules, smaller anthers, a shorter pistil, and less pollen. In a few cases (*Panicum clandestinum*) for example, chasmogamous spikelets and cleistogamous spikelets may occur in the same inflorescence. Two-rowed erect-eared barley (*Hordeum distichon erectum*) bears only cleistogamous flowers.

Pollination.—Wind is the chief agent in the dissemination of grass pollen. In all grasses the pollen is light and dry, and hence easily blown. Insects play a very unimportant part in this process.

Most grass flowers open to shed their pollen, that is show *chasmogamy*. In some grasses, however, the glumes do not spread apart, thus allowing the stamens and pistils to become exposed. Flowers that do not open are said to show *cleistogamy*.

Fruit.—In all grasses, the fruit is one-seeded, dry, and does not split open at maturity to allow the seed to escape. The pericarp (ovary wall) is firmly attached to the seed coat. There is an abundance of starchy endosperm. Sometimes the grain is closely adherent to the palet and lemma, as in most barleys and oats. The grass fruit is called a *grain* or *caryopsis*.

Phylogeny of Grasses.—The history of the evolution of a group of organisms is *phylogeny*. What is the origin of the

grasses? Are they primitive forms, the progenitors of such closely related groups as the lilies and other common monocotyledonous plants; or are they a reduced group? By those who hold the latter view, which is more widely accepted, grasses are considered to have come from lily-like plants by a reduction and modification of a number of parts of the flower. Examination of the floral diagram of a typical lily flower is shown in Fig. 32 A. It has two sets of floral segments (which together constitute the *perianth*) which alternate, two whorls of stamens, three in each whorl, and a pistil divided into three chambers, hence tri-carpellary. The stamens of one whorl alternate with those in the other; those of the outer whorl alternate with the inner segments of the perianth. The three carpels alternate with the inner stamens. In Fig. 32 B is shown the floral diagram of a grass flower with the rudimentary or missing parts shaded. According to the view that grasses are reduced lilies, there was a reduction in the lobes of the pistil from three to one, a loss of one whorl of stamens, and a reduction in the number of perianth lobes.

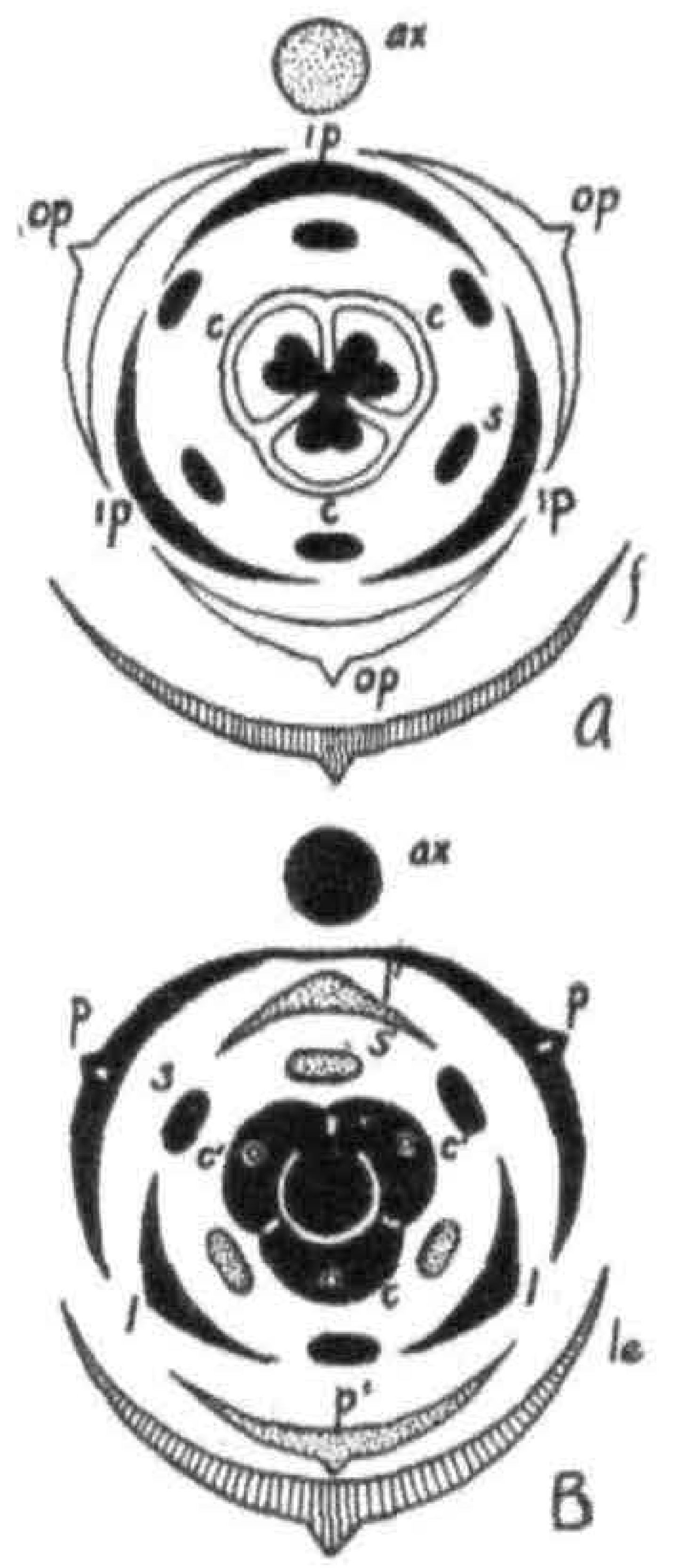


FIG. 32.—Diagram of *A* lily flower, and *B* grass flower showing homologous structures. *A*, *f*, bract; *ax*, axis; *op*, outer perianth; *ip*, inner perianth; *s*, stamens; *c*, tricarpellary ovary. *B*, shaded structures are aborted; *le*, lemma (bract); *ax*, axis; *p* and *p'*, palet (outer perianth); *l* and *l'*, lodicules (inner perianth); *s* and *s'*, two whorls of stamens; *c*, tricarpellary ovary. (*B after Schuster*.)

Although commonly assumed to be one-carpelled, the grass pistil is really tri-carpellary. This latter view is held by a number of morphologists. In all grasses, the pistil has three fibro-vascular bundles. Two of these extend to the style branches and the third (dorsal) extends to the dorsal lobe of the pistil or to

the third rudimentary style branch, when present. This third bundle bears the ovule. In *Streptochæta* and *Bambusæ*, there are three styles. Furthermore, it should be noted that the three vascular bundles stand in regular alternation with the second whorl of stamens and the inner whorl of the perianth.

Rowlee, in a study of *Arundinaria*, a bamboo, concluded that the lodicules represent the inner perianth whorl. The common view, as presented by Hackel, has been that lodicules are bracts. Schuster's researches substantiate those of Rowlee. He finds that, although two lodicules is the common number, a third (anterior) one occasionally occurs (in Bambusæ); that the two (posterior) lodicules are not bound together at first but originate separately; that in one grass genus (*Streptochæta*), at least, the three lodicules are independent. From these studies, it appears that the lodicules, morphologically, are to be considered as the inner perianth whorl. The same worker (Schuster) considers the palet to represent the outer perianth whorl of this lily-like flower. The palet is usually two-keeled or two-nerved. There are cases in which the palet is divided into two parts, and in which there is a third part in a rudimentary condition. In the majority of grasses, the two parts of the palet arise from separate primordia, which are united; the third, outer perianth whorl aborts. In this connection it should be noted that the palet of einkorn (*Triticum monococcum*) divides into two parts, at maturity, on the median line, each half bearing a keel (Fig. 41).

According to the view presented above, the grass spikelet is interpreted as a modified branch, bearing a number of distichous bracts. The two lower bracts (glumes) are sterile. The flowers occur in the axils of the lemmas. The flower is of the lily type. The outer perianth whorl is represented by the palet, the inner by the lodicules; one whorl

(inner) of stamens (usually, not always) is aborted; the pistil is three-carpelled. Hence, the conclusion is arrived at that grasses are derivates of a lily-type of flower.

Grass-like Plants.—Grasses are closely related to the sedges (*Cyperaceæ*). Sedges, however, have solid stems, usually three-angled, leaves with closed sheaths, and the fruit an achene. In the achene the pericarp or mature ovary wall is not firmly grown to the seed coat which immediately adjoins on its inner surface. The achene and the grain are both dry, one-seeded fruits that do not split (dehisce) at maturity, but in the grain the mature ovary wall is closely adherent to the seed coat. In grasses, as pointed out on page 77, the leaves are two-ranked or distichous. In sedges, however, the leaves are three-ranked, or one-third alternate. Sedges usually grow in wetter situations than grasses and are often harsher in texture, due to the deposition of silica in the stems and leaves. There are certain rushes (*Juncaceæ*), other than rush-like sedges, which are grass-like in appearance. These, however, are distinguished from the grasses by the presence of a perianth of six distinct glume-like segments.

References

Baillon, H.: L'evolution de l'inflorescence dans les Graminees. Bul. Soc. Linn. Nord, France, 1894, 1123–1128.

Bruns, E.: Der Grasembryo. Flora, 76: 1–33, 1892.

Chase, Agnes: Notes on the Cleistogamy of Grasses. Bot. Gaz., 45: 135–136, 1908.

Doell: Untersuchungen über den Bau der Grasblute. Jahresber. Mann. Ver. f. Naturk., 1868, xxxiv and 1870, xxxvi.

Goebel, K.: Ein Beitrag zur Morphologie der Graser. Flora, 1895, Erganzungsband.

Guerin, P.: Recherches sur le development du tegument seminal et du pericarpe des graminees. Ann. Sci. Nat. Bot., 9: 1–59, 1899.

Hackel, E.: Über das Aufblühen der Graser. Bot. Ztg., 33: 432, 1880. Untersuchungen über die Lodiculæ der Graser. Engler's Jahrb., 1: 336–361, 1881.

The true grasses. Transl. from German by F. L. Scribner and E. A. Southworth. Henry Holt & Co., New York, 1890.

Über Kleistogamie bei den Gräsern. Osterr. Bot. Ztschr., 55: 81–88. 143–154, 180–186, 1906.

HITCHCOCK, A. S.: A Text-book of Grasses with Especial Reference to the Economic Species of the United States. The Macmillan Co., New York, 1914.

JUMELLE, HENRI: Note sur la constitution du fruit des Graminees. Compt. Rend. Acad. Sci. (Paris), 107: 285, 1888.

KENNEDY, P. B.: The Structure of the Caryopsis of Grasses with Reference to Their Morphology and Classification. U. S. Dept. Agr., Div. Agros., Bul. 19, 1900.

LAMB, WILLIAM, H.: The Phylogeny of Grasses. Plant World, 15: 264–270, 1912.

PIPER, C.: The Terminology of the Parts of the Grass Spikelet. Science, n. s., 23: 789–790, 1906.

ROWLEE, W. W.: The Morphological Significance of the Lodicules of Grasses. Bot. Gaz., 25: 199–203, 1898.

SCHUSTER, JULIUS: Über die Morphologie der Grasblüte. Flora, 100: 213–266, 1910.

WALKER, E. R.: On the Structure of the Pistils of Some Grasses. Thesis, Univ. Nebr., 1906.

WARD, H. MARSHALL: Grasses, a Handbook for Use in the Field and Laboratory. Cambridge, 1901.

TRUE, RODNEY: On the Development of the Caryopsis. Bot. Gaz., 18: 212–226, 1893 (contains bibliography on development of grain).

CEREALS

Cereals are those grasses which are grown for their grain. Buckwheat is sometimes considered a cereal because its fruit (achene) is ground into flour, but it is not so considered here.

Buckwheat, flax, and others, which are often raised for their seed or fruit, but are not grasses, are discussed wherever they happen to come in the botanical order of treatment followed here.

KEY TO GROUPS (GENERA) OF IMPORTANT CEREALS[1]

[1] *What is a "key," and how is it used?* Throughout the following pages there will be a number of "keys." A "key" is a convenient form for dis-

tinguishing one plant from another, or one plant group from another. It presents in concise form the principal differences between the plants considered. It also enables one to determine the proper classification of an unknown plant. Most of the "keys" in the following pages are "artificial;" that is, the characters used are obvious ones. The "keys" herein are constructed on the dichotomous plan, *i.e.*, by twos. The entire number of groups under consideration, whether these be species, genera, families, or higher divisions, is first divided into two subgroups; each of the subgroups is subdivided into two groups, and so on. The alternatives are equally indented on the page. In the key to the genera of cereals, they are first divided into two large groups, the first including *Zea*, *Oryza*, *Andropogon* and *Millets;* and the second, *Avena*, *Secale*, *Triticum* and *Hordeum*. It is seen that those genera of the first group have "spikelets falling from the inflorescence entire . . ." while those of the second group have "spikelets falling from the inflorescence without the glumes. . . " Each of the two large groups is again separated into two subdivisions. For example, the genera *Avena*, *Secale*, *Triticum* and *Hordeum*, are subdivided on the basis of their inflorescences. *Avena* has a panicle inflorescence, while *Secale*, *Triticum*, and *Hordeum* have a spike inflorescence.

Let us suppose that we have a cereal in hand, the genus of which we wish to determine. First of all, it would be necessary to decide whether the "spikelets fall from the inflorescences entire . . . ;" or "spikelets fall from the inflorescence without the glumes . . . ;" if it has the characters of the second alternative, we know it is either oats, rye, wheat or barley. Should the specimen in hand have a spike inflorescence, oats is eliminated from consideration, and the plant must be either rye, wheat or barley. If, by examination of this unknown plant, we find now that there are "three spikelets at each joint of the rachis," it must belong to the genus *Hordeum* (barley).

The "key" shows many of the characteristics of a group. Consider *Triticum* (wheat), for example. One can see by the key that "spikelets fall from the inflorescence without the glumes, which remain attached to the rachilla; spikelets one-many-flowered; rachilla often produced beyond the upper glume; grain with a longitudinal furrow; tuft of hairs at tip of ovary." Furthermore, that the "inflorescence is a spike;" that there is "one spikelet at each joint of the rachis," and the "glumes are not bristle-like, but broad."

Spikelets falling from the inflorescence entire (glumes attached to grain), one-flowered, or if two-flowered the lower one staminate; rachilla not produced beyond the flowers; grain without a longitudinal furrow; no tuft of hairs at tip of ovary.

Flowers staminate and pistillate; borne in separate inflorescences on the same plant, *i.e.*, monœcious (Fig. 60), *Zea* (maize or Indian corn).

Flowers perfect or staminate; when the staminate are present, borne in same inflorescence with perfect.

Spikelets much compressed laterally (Fig. 79), *Oryza* (rice).
Spikelets cylindrical or somewhat compressed dorsally.
Lemma and pallet thin and papery, much more delicate in texture than the empty glumes (Fig. 75), *Andropogon* (sorghum, milo, broom corn, etc.)
Lemma and palet, at least of perfect flower, never thin and papery, parchment-like or leathery, hard and shiny, very different in color and appearance from the glumes (Fig. 87), *Chætochloa*, *Echinochloa*, *Panicum*, *Pennisetum* (millets).
Spikelets falling from the inflorescence without the glumes, which remain attached to the rachilla; spikelets one to many-flowered; rachilla often produced beyond the upper glume (Fig. 50); grain with a longitudinal furrow (Fig. 36); tuft of hairs at tip of ovary (Fig. 36).
Inflorescence a panicle (Fig. 48), *Avena* (oats).
Inflorescence a spike.
One spikelet at each joint of rachis.
Glumes bristle-like (Fig. 58), *Secale* (rye).
Glumes not bristle-like, broad (Fig. 29), *Triticum* (wheat).
Three spikelets at each joint of rachis (Fig. 52), *Hordeum* (barley).

Key to Small-grain Seedlings[1]

[1] This key is taken verbatim from Carrier. The "collar" is a narrow band, usually of different color from the sheath and blade, at the junction of leaf and blade. The "claw-like appendages" are the auricles.

Collar without claw-like appendages, Oats (*Avena sativa*).
Collar with claw-like appendages which clasp the stem more or less.
Claws hairy.
Sheaths and blades finely pubescent, soft, and velvety, Emmer (*Triticum dicoccum*).
Sheaths and blades not pubescent.
Collar and claws large, Spelt (*Triticum spelta*).
Collar and claws slender, Wheat (*Triticum æstivum*).
Claws not hairy.
Collar and claws large and prominent.
Nerves of blades not prominent, upper surface rough, Barley (*Hordeum sativum*).
Nerves of blades broad and prominent, smooth on upper surface, Polish wheat (*Triticum polonicum*).
Collar and claws slender.
Blades and sheaths sparsely hairy, Rye (*Secale cereale*).
Blades and sheaths free from hairs, Durum wheat (*Triticum durum*).

References

AARONSOHN, A.: Über die in Palästina und Syrien wildwachsend aufgefundenen Getreide-arten. Verhandl. K. K. Zool. Bot. Gesell. Wien., 59: 385–500, 1909.

Contribution a l'histoire des cereales. Bul. Soc. Bot. (France), 1909.

ATTERBERG, A.: Die Nachreife des Getreides. Landw. Versuchstat., 67: 129–143, 1907.

CARLETON, M. A.: The Small Grains. The Macmillan Co., 1916.

CARRIER, LYMAN: The Identification of Grasses by Their Vegetative Characters. U. S. Dept. Agr. Bull. 461: 1-30, 1917.

DEHERAIN UND DUPONT: Über den Ursprung der Stärke im Getreidekorn. Comp. Rend. Acad. Sci. (Paris), 133: 774, 1902.

DESRIOT, A.: Les cereales, 2 ed., Paris, 1910, Hachette et cie.

EKKERT, F.: Über Keimung, Bestockung und Bewurzelung der Getreidearten. Inaug. Diss. Leipzig, 1873.

FRUWIRTH, C.: Das Blühen des Getreides. Jahrb. Deut. Landw. Gesell., 2: 68–75, 1907.

FRUWIRTH, W.: Die Züchtung der landwirtschaftlichen Kulturpflanzen. Berlin, 1910.

KOERNICKE, F. and WERNER, H.: Handbuch des Getreidesbaues. I. Die Arten und Varietäten des Getreides. II. Die Sorten und der Anbau des Getreides. Berlin, 1885.

Über die Entstehung und das Verhalten neuer Getreidevarietäten. Archivs für Biontologie, 1908.

KRAUS, C.: Die Lagerung der Getreide. Stuttgart, 1908.

KNISSLING, L.: Untersuchungen über die Keimung der Getreide. Landw. Jahrb. (Bayern), 1: 449–514, 1911.

KUDELKA, F.: Über die Entwicklung und den Bau der Frucht und Samenschale unserer Cerealien. Landw. Jahrb., 4: 461–478, 1875.

HITIER, H.: Les cereales secondaires. Seigle, Mais, Sarasin, Millet, Rhiz. Paris, 1910.

HOFFMAN: Das Getreidekorn. Berlin, 1912.

HUNT, T. F.: The Cereals of America. Orange Judd Co., New York, 1905.

NOWACKI, A.: Anleitung zum Getreidebau, IV. Berlin, 1905.

RIMPAU, W.: Das Blühen des Getreides. Landw. Jahrb., 1882 (contains the old literature on the blooming of grasses).

Untersuchungen über die Bestockungen des Getreides. Jahrb. Deut. Landw. Gesell., 1903.

SCHINDLER, FRANZ: Der Getreidebau. Berlin, 1909.

SCHMID, B.: Bau und Funktionen der Grannen unserer Getreide-arten. Bot. Centralbl., 76, 1898.

SCHMIDT, O.: Über den Entwicklungverlauf beim Getreide. Ein Beitrag zur Sortenkenntnis. Landw. Jahrb., 45: 267–324, 1913.

SCHULZ, A.: Die Geschichte der kultivierten Getreide, I. Halle, 1913.

SCHULZ, B.: Wurzelatlas. Darstellung natürlicher Wurzelbilder der Halmfrüchte in verschiedenen Stadien der Entwickelung. Berlin, 1911.

SEELHORST, V.: Versuche über die Möglichkeit einer Bewurzelung und Adventivtriebbildung an oberirdischen Knoten von Getreidepflanzen. Jour. Landw., 1902.

WEAVER, JOHN E.: Root Development in the Grassland Formation. A Correlation of the Root Systems of Native Vegetation and Crop Plants. Carnegie Inst. of Wash. Pub. 292: 1–151, 1920.

CHAPTER X

TRITICUM (Wheat)

Wheat is an annual. Under our cultural conditions, there are two seasonal forms, winter annual, or winter wheat, and summer annual, or spring wheat.

Roots.—Wheat has a fibrous root system. In the germination of the grain, the primary root takes the lead; often, two pairs of lateral roots appear on either side of the primary. These laterals originate from the hypocotyl. A sixth root sometimes arises at a point near the base of the plumule and behind the epiblast. Rarely, a third pair of rootlets may appear above the second pair. Thus the seminal or temporary root system may sometimes consist of eight roots. It usually dies before the plant is fully grown. Permanent roots which are adventitious appear in whorls at the nodes some distance above the temporary roots. The first whorl of permanent roots is generally about 1 inch below the soil surface, no matter at what depth the grain was planted (Fig. 4). In their growth, the whorls of permanent roots curve outward and then downward, taking an almost vertical course. They branch very freely near the soil surface and form within the first 2 or 3 feet a fine network, which constitutes a large absorbing surface. However, many of the roots of wheat reach a depth of 4 feet, or even more under favorable soil conditions. Weaver has shown that the average "working depth" of wheat roots in the short-grass formation of the plains of western United States is 2.3 feet, in the mixed prairie 3.6 feet, and in the true prairie 3.8; and that the maximum penetration of the roots in each of the above plant

communities is 2.7 feet, 4.4 feet and 5.4 feet respectively. It has been observed that the aggregate length of all the roots of a one-year-old wheat plant amounts to 500 to 600 meters. The number of roots increases with the number of tillers.

Stems.—The stems of wheat are of the general grass type. In wheat, there are usually six joints (*internodes*), the sixth being the spike-bearing one. The lowest joint usually remains short, sometimes less than 1 millimeter long; the second joint also remains short; the sixth one is the longest. In most wheats, the internodes are hollow, but in a few varieties of macaroni and Poulard wheats, they are filled with pith.

Foliage Leaf.—The wheat leaf is of the ordinary grass type. The blade varies considerably; the sheath is split; the ligule is thin and transparent; the auricles are conspicuous, although not as prominent as those in barley. It of interest to observe that the first foliage leaf of wheat differs from all succeeding ones in that its apex is more blunt and stiff. It is believed that these characteristics enable it to push its way through the soil more easily.

Inflorescence.—Wheat flowers are arranged in spikelets and the spikelets into a "*head*" or *spike* (Fig. 32). The spike varies in size, compactness and form in the different types of wheat. Fifteen to twenty fertile spikelets in a head is a fair average, but spikes have been observed with a number considerably greater. An abundance of water in the soil during the early stages of development has been found to increase the number of spikelets in a head. The *rachis* or main axis of the spikelet is zigzag in shape (Fig. 51). Each joint of the rachis is flattened and curved, the concave surface being on the side next to the spikelet. There is but one spikelet at each joint of the rachis. There are usually numerous short so-called "basal hairs" at the base of each

spikelet. The lower spikelets of the head are often sterile; less frequently, the terminal spikelet is sterile (as in einkorn).

Spikelet.—The number of flowers in a wheat spikelet varies from three to nine, but one or more of the upper ones are usually sterile. It has been shown that the number of flowers that reach maturity in a spikelet may be increased by an ample supply of water during the period when the flowers are developing. It is quite probable that there is a "critical period" in the life of the plant at which time the supply of moisture coming to the plant has the maximum effect in the production of flowers. This critical period is probably during the early stages of flower formation, quite a while before the time of heading.

The wheat spikelet dissected in Fig. 30 has four flowers, three of which have matured grain. The fourth flower is sterile. In Fig. 29, the lemmas of four flowers are visible. As a rule, but two grains mature. In some varieties, most of the spikelets mature three grains, and less frequently four.

The glumes are broad, varying much in shape, color, smoothness or hairiness, width and distinctness of keel, length and sharpness of tip. It has been shown that, in general, the second kernel of a spikelet is the heaviest, the first next heaviest, then the third, fourth, etc.

Flower (Fig. 31).—There are three stamens with thread-like filaments and rather large anthers. The single ovary has two feathery stigmas. There are two lodicules. As was pointed out on page 84, the palet represents the outer perianth whorl, and the lodicules the inner perianth whorl.

Opening of Flower and Pollination.—It has been shown (in a variety of winter wheat-Fultz) and under the meteorological conditions of Washington, D. C., that 86.2 per cent. of all flowers bloomed during daylight, 6.9 per cent. during twilight and 6.9 per cent. during the night. On the average,

it required 3 minutes and 36 seconds for a flower to open fully and the anthers to assume a pendant position, and 26.5 minutes for the flower to open and to completely close again.

Fluctuation in the time of blooming is less noticeable in einkorn than in other wheats, and less marked on sultry days following rainy days in all types of wheat. Polish wheat shows the most marked fluctuations. Temperature and moisture are certainly the important external factors determining the time of blooming. There appears to be considerable variation even in the same variety.

It is stated that the swelling of the lodicules brings about the separation of the lemma and palet and hence the opening of the flower. Grass flowers in which the lodicules are membranous or wanting remain closed, while those in which there is only slight swelling of the lodicules open but to a small extent. It is observed that a mechanical stimulus, such as is brought about by running the head of wheat through the hands, or by the contact of one head of wheat with another as they sway in the wind, often causes the glumes to open quite rapidly.

In the unopened wheat flower, the filaments are short, the stigmas erect and in contact. The palet and lemma separate, first slowly and then quickly. The filaments then elongate rapidly, pushing the anthers up and outside of the glumes. The anthers are shedding pollen before the flower is fully open, and they continue to do so until it closes again. All three anthers do not always protrude from the flower, and, in some instances, none may escape before the flower closes. The first flowers to open are those situated about one-third of the way from the tip of the spike, and the basal flower of any spikelet is the first to open. The others in the spike follow in succession above and below this point. The head completes its flowering usually in several days. In

the plant as a whole, flowering takes place first on the primary culm, and is followed by those on the "tillers" in the order of their origin.

In northern cold or wet climates, close pollination (*autogamy*) is the rule in nearly all wheats, although a very small percentage (less than 1 per cent.) of natural crossing may occur. Durum wheat, however, has the habit of cross-pollination (*xenogamy*), and it has been suggested that this behavior is partly responsible for its better adaptation to dry climates, and for its greater disease resistance and vigor. Cross-pollination is quite common in the primitive wheat, which is an inhabitant of a dry, warm country. It appears that cross-pollination is the rule in hot, dry localities, such as certain parts of India.

Artificial Cross-pollination.—One of the chief means of wheat improvement is hybridization. This necessitates the operation of artificial cross-pollination. In this process, the glumes of the flower of the female parent are spread apart and the three stamens removed; this is done just before the anthers are mature. On the same day, or on the following morning, pollen is taken from the mature anthers of the plant to serve as the male parent, and placed between the glumes of the flower from which the stamens have been removed. The chances are that the pollen will reach the stigma branches of the emasculated flower, germinate, and effect cross-fertilization.

Fertilization and Maturing of Grain.—It is stated that fertilization in wheat normally occurs between one and two days after pollination. This interval represents the time necessary for the pollen grain to germinate, and for the pollen tube to grow down through the stigma to the embryo sac in the developing ovule. This interval no doubt varies in different varieties and under different environmental conditions, particularly temperature. Cool weather will retard

germination of the grain, and growth of the pollen tube, and thus affect the "setting" of grain.

After fertilization, the embryo begins to develop, the endosperm to store reserve material, and the seed and fruit walls to undergo marked changes.

Embryo.—In the very young stage, prior to fertilization, the axis of the ovule is parallel with that of the ovary. Soon in its development, the ovule turns so that its micropyle is directed downward (Fig. 33). At first, the young ovule does not fill the ovary cavity, but soon does so by further growth. The ovule is attached along its side to the ovary. The groove indicates the position and extent of this attachment. The first pair of seminal (seed) rootlets appears in the embryo about four weeks after pollination.

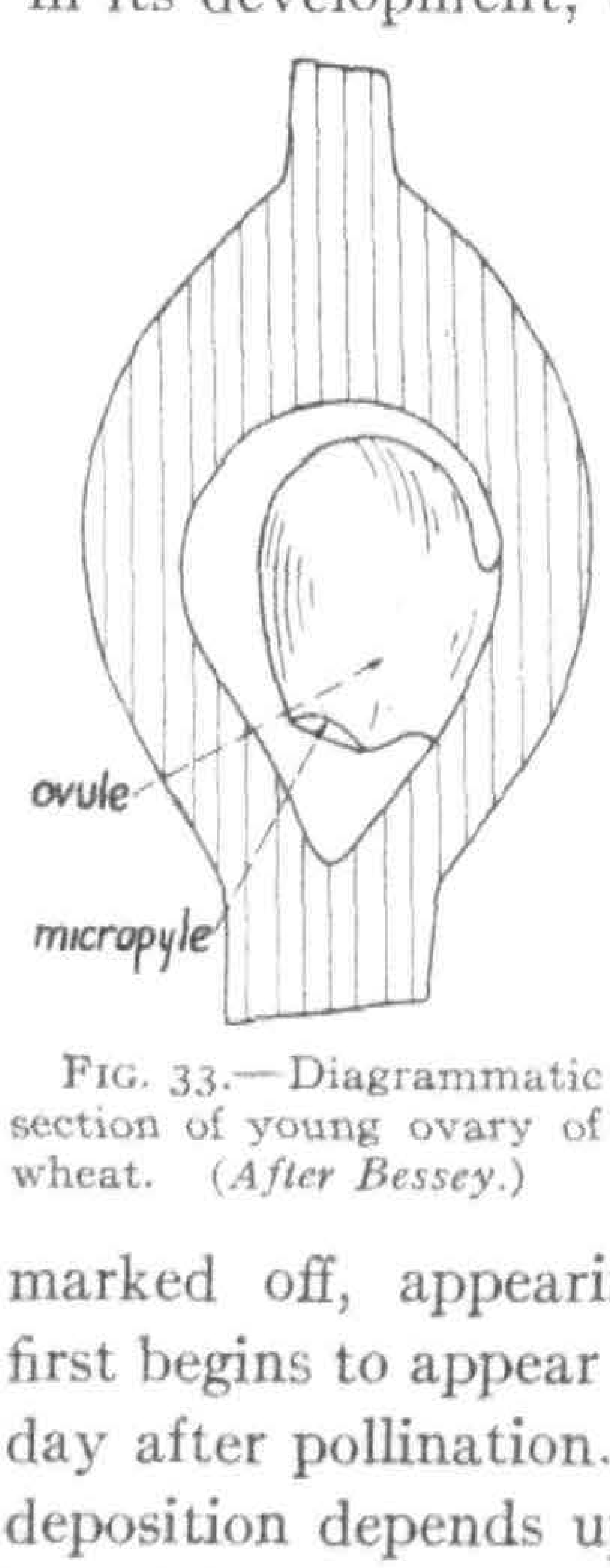


FIG. 33.—Diagrammatic section of young ovary of wheat. (*After Bessey.*)

Endosperm.—In about a week or ten days after fertilization, a definite endosperm tissue is formed within the embryo sac. About seven or eight days later, the aleurone layer is marked off, appearing first on the dorsal side. Starch first begins to appear in the "flank" cells about the eleventh day after pollination. The actual time of the beginning of deposition depends upon the relative activity of the leaves in making sugar and of the embryo in assimilating it. Infiltration of starch is complete in about five weeks after pollination. It is held that reserve nitrogenous matter enters the endosperm at the same time as the starch.

Grain Coats.—Before fertilization, the grain coats are as follows:

1. *Outer epidermis*—one row of cells.

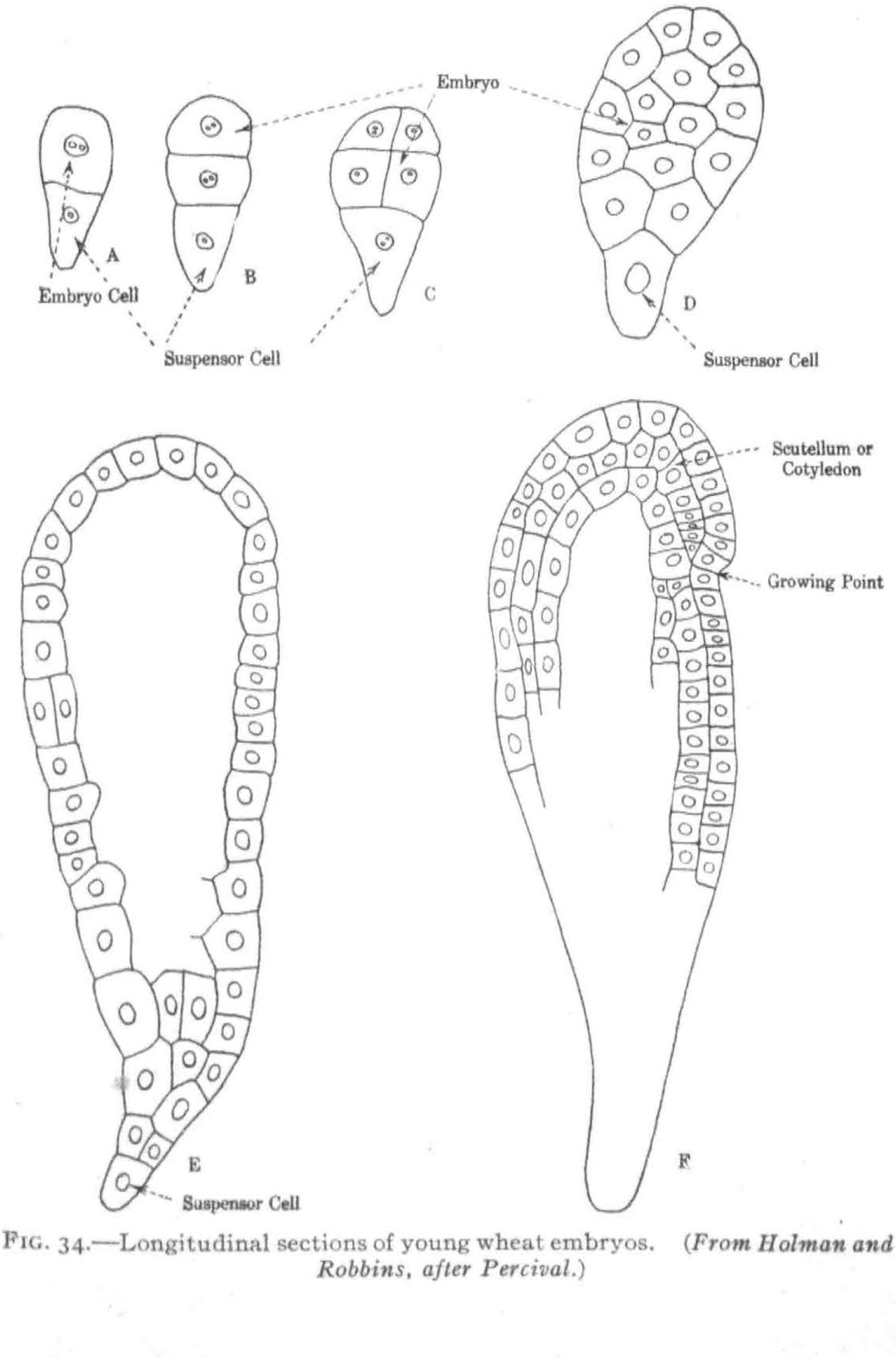


FIG. 34.—Longitudinal sections of young wheat embryos. (*From Holman and Robbins, after Percival.*)

2. *Parenchyma layer*—many rows of colorless cells.
3. *Chlorophyll layer*—one row of cubical cells, sometimes two, and several in the groove region.
4. *Inner epidermis*—one row of small cells.
5. *Outer integument*—two layers.
6. *Inner integument*—two layers.
7. *Nucellus*—several layers of thin-walled parenchyma cells, all bounded by a distinct nucellar epidermis.

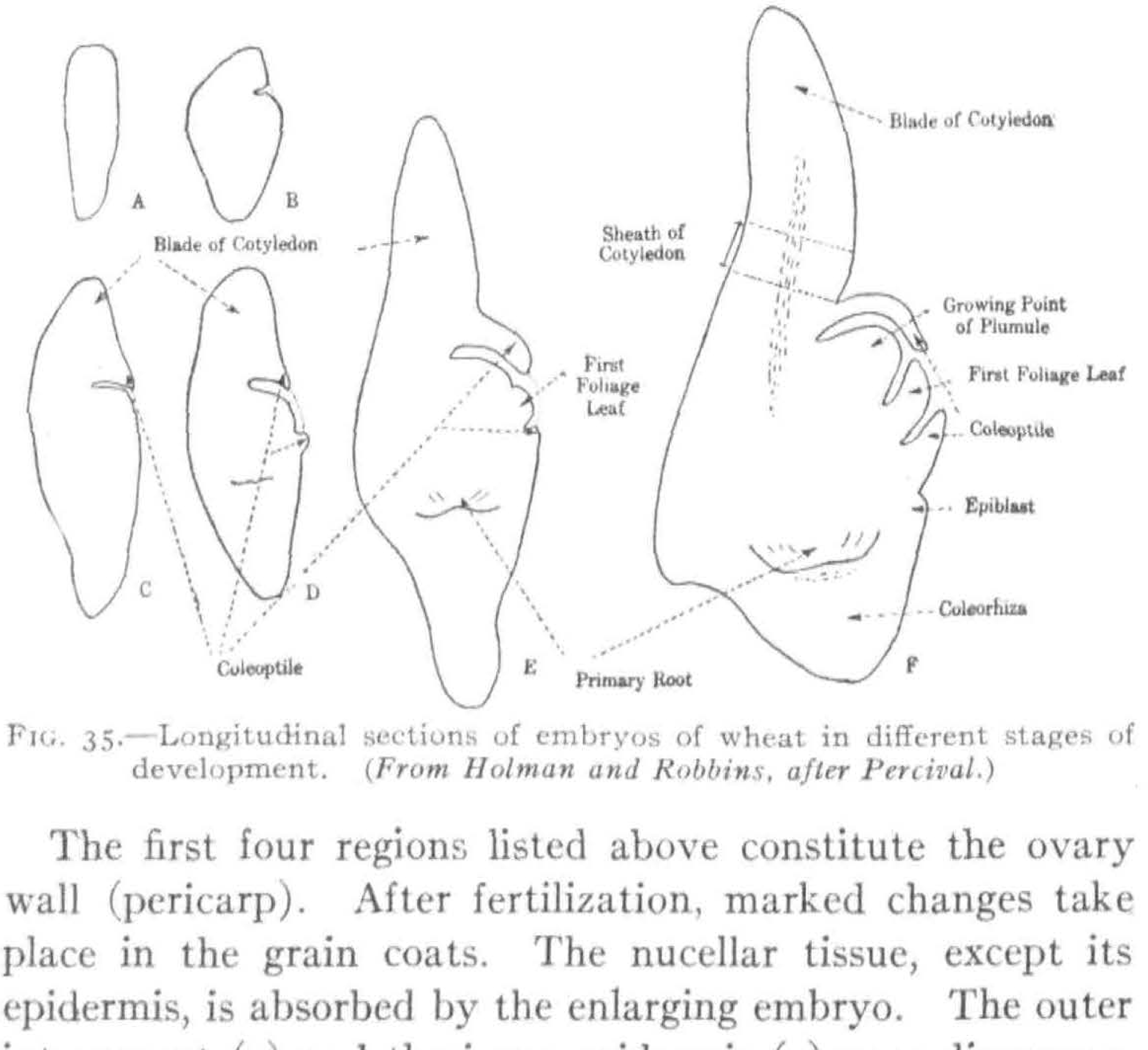


FIG. 35.—Longitudinal sections of embryos of wheat in different stages of development. (*From Holman and Robbins, after Percival.*)

The first four regions listed above constitute the ovary wall (pericarp). After fertilization, marked changes take place in the grain coats. The nucellar tissue, except its epidermis, is absorbed by the enlarging embryo. The outer integument (5) and the inner epidermis (4) soon disappear. At first, starch is deposited in the entire ovary wall. At the time of resorption of the ovary wall, deposition of starch within it ceases, and its appearance begins in the endosperm. Resorption of the ovary wall begins in the layer just outside the chlorophyll-bearing layer and extends slowly out to the

epidermis. Two to four layers next to the epidermis persist in the mature grain. The chlorophyll cells become longer, lose their chlorophyll, and thicken their walls. In the process of maturation, the ovary wall or pericarp becomes firmly attached to the outer layer of the inner integument of the ovule. This behavior seems to be well demonstrated in all grasses investigated. The firm attachment of the pericarp to the ovule distinguishes the grain or caryopsis from the achene.

Ripening Stages.—It is customary to speak of four stages in the ripening of the grain: (1) milk-ripe or green-ripe stage; (2) yellow-ripe, gold-ripe, or "dough" stage; (3) full-ripe stage, and (4) dead-ripe stage.

In the *milk-ripe* or *green-ripe* stage, the embryo is already fully developed. The grain changes from pale green to dark green in color, which change is due to the resorption of several layers of the ovary wall, through which the chlorophyll layer now shows. The endosperm cells are filled with a watery sap in which are suspended a number of starch grains; hence, when the grain is squeezed a white, milky juice comes out.

In the *yellow-ripe, gold-ripe,* or "*dough*" stage, the cells of the ovary wall become thicker. The lumina of inner integument cells decrease in size, due to an increase in the thickness of their walls. The color of the grain changes from green to yellow, and the endosperm becomes tough and waxy.

The *full-ripe* stage follows close upon the preceding. As a result of water loss, the different cell layers become distorted. The grain becomes harder and firmer. Grain is usually harvested while in this stage.

If the crop is now left in the field, the grain becomes brittle; it is then said to be in the *dead-ripe* stage.

Nowacki gives the following analyses of grains of wheat at different stages of development:

	Water content of grain	Volume of 100 grains, cm².	Dry substance in 100 grains, grams
Milk-ripe (*a*) July 9......	51.47	5.31	2.86
Milk-ripe (*b*) July 13......	47.69	5.17	3.58
	34.37	5.07	4.44
Yellow-ripe July 20......	25.73	4.28	4.19
	12.91	3.08	3.80
Full-ripe July 23......	12.97	3.52	4.22

The maturity of the grain appears to affect its vitality. Kedzie has shown that wheat collected in the dough stage yielded 25 bushels per acre; in the full-ripe stage, 30 bushels per acre, and in the dead-ripe, 28 bushels. The dead-ripe stage produced the most vigorous seed, as was determined by the length to which the plumule would grow. For example, in the above experiment wheat collected in the dough stage produced a plumule 9 inches long, in the full-ripe stage 10.1 inches long, and in the dead-ripe stage 11 inches long. Similar experiments with rye have shown that plants from immature seeds lack vigor, and also that a large percentage fail to germinate.

The Mature Grain.—The average weight of 100 kernels of common bread wheat is about 3.8 grams. Durum wheats weigh more per 100 grains. Although the results are conflicting, there are insufficient positive results to warrant the belief that large plump seeds will give uniformly greater yields than small seeds, especially when such seeds are secured by means of the ordinary fanning mill. It is known that not all the grains in a spikelet are the same size and weight—the second is the heaviest, the first and third about equal in weight, and the fourth and fifth, if present, are lightest of all. It is obvious that all grains from a spikelet regardless of their size, have the same heredity. And a light seed from

a spikelet usually will, under similar environmental conditions, develop into a plant with as much vigor as one from a heavy seed from the same spikelet. In the selection of seed wheat, the individual plant should be the basis of selection, when such method is practicable, rather than to depend upon seed from the bin or sack, which is the offspring of many different parent plants.

There is a tuft of hairs, the *brush* (Fig. 36) at the small (stigmatic) end of the grain, and at the opposite end the embryo. Along the side of the grain, facing the palet, is a *groove* or *furrow*. This groove marks the region of attachment of seed to ovary. The position of the embryo may be seen easily at the base of the grain. Fig. 36 shows a cross-

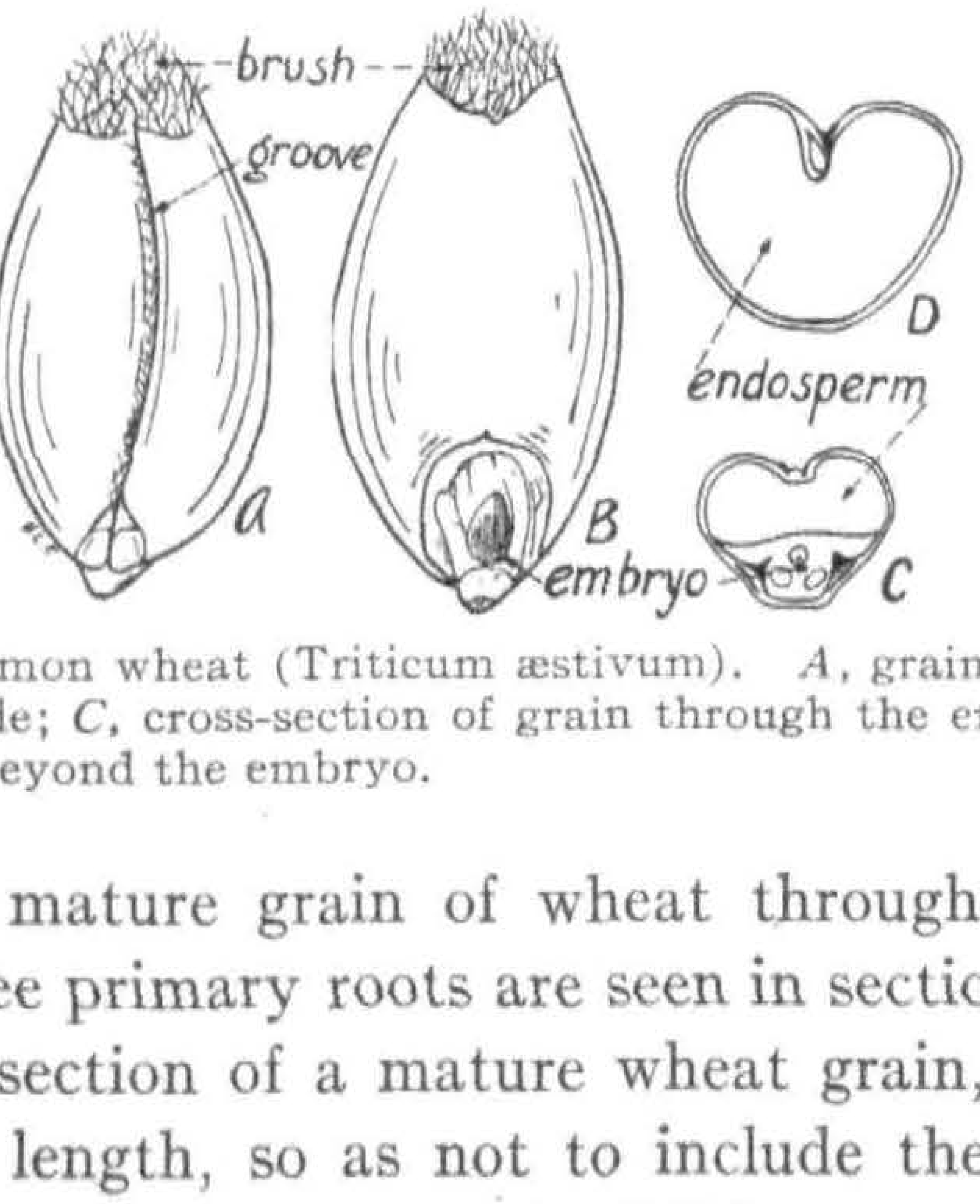


FIG. 36.—Common wheat (Triticum æstivum). *A*, grain, groove side; *B*, grain, embryo side; *C*, cross-section of grain through the embryo; *D*, cross-section of grain beyond the embryo.

section of a mature grain of wheat through the embryo region. Three primary roots are seen in section.

In a cross-section of a mature wheat grain, cut at right angles to its length, so as not to include the embryo, the following layers, may be recognized (Fig. 37):

1. *Ovary wall* or *pericarp*, of several cell layers.
2. *Testa*, two layers of inner integument.
3. *Nucellus.*
4. *Aleurone layer*, outermost layer of endosperm.
5. *Starchy endosperm.*

Ovary Wall or *Pericarp*.—The pericarp of the mature grain is composed of several layers of highly compressed cells, the original cavities of which can scarcely be distinguished. The walls are thickened, cuticularized and lignified. The chlorophyll-bearing layer, now colorless, is below these layers. Its cells are marked by numerous narrow transverse pits. The outside wall of chlorophyll cells is thin, while the inside wall, next to the integument, is thick. In tangential view, chlorophyll-bearing cells appear strongly thickened, rounded at the ends, and closely fitting, thus leaving no intercellular spaces. In rye, these same cells as seen in tangential section are pointed at the ends.

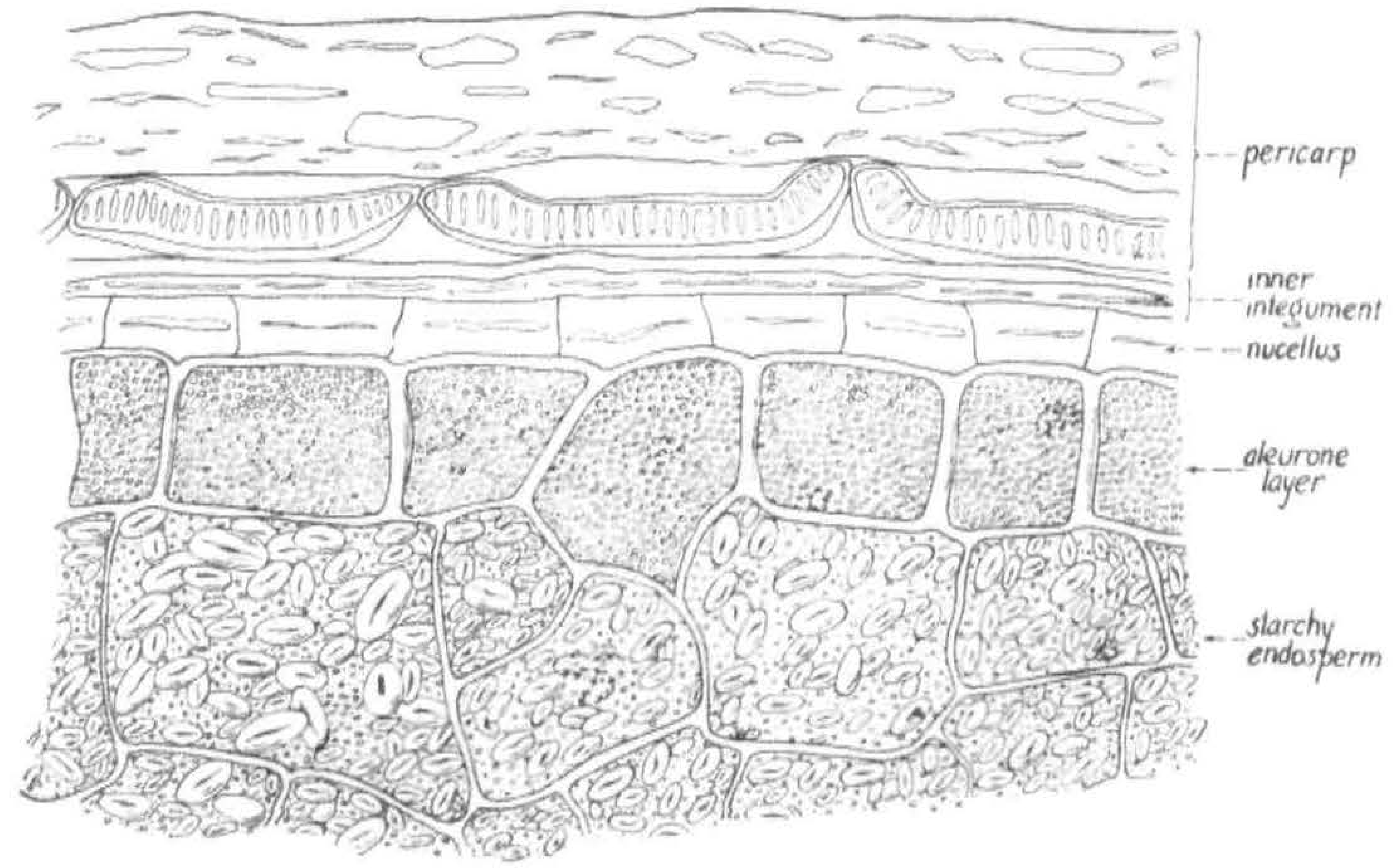


FIG. 37.—Microscopic section of wheat grain.

The grains of spelt, emmer, and einkorn have the palet and lemma attached, and in these the pericarp is more weakly developed than in the types of wheat with naked grains. In all wheats, the layers of the grain, both fruit and seed, are much thinner at the embryo end than in the other parts of the fruit. It is known that the greatest amount of absorption of water takes place at the embryo end.

Testa (episperm).—It has been noted that, in the developing wheat grain, the testa is composed of two integuments of

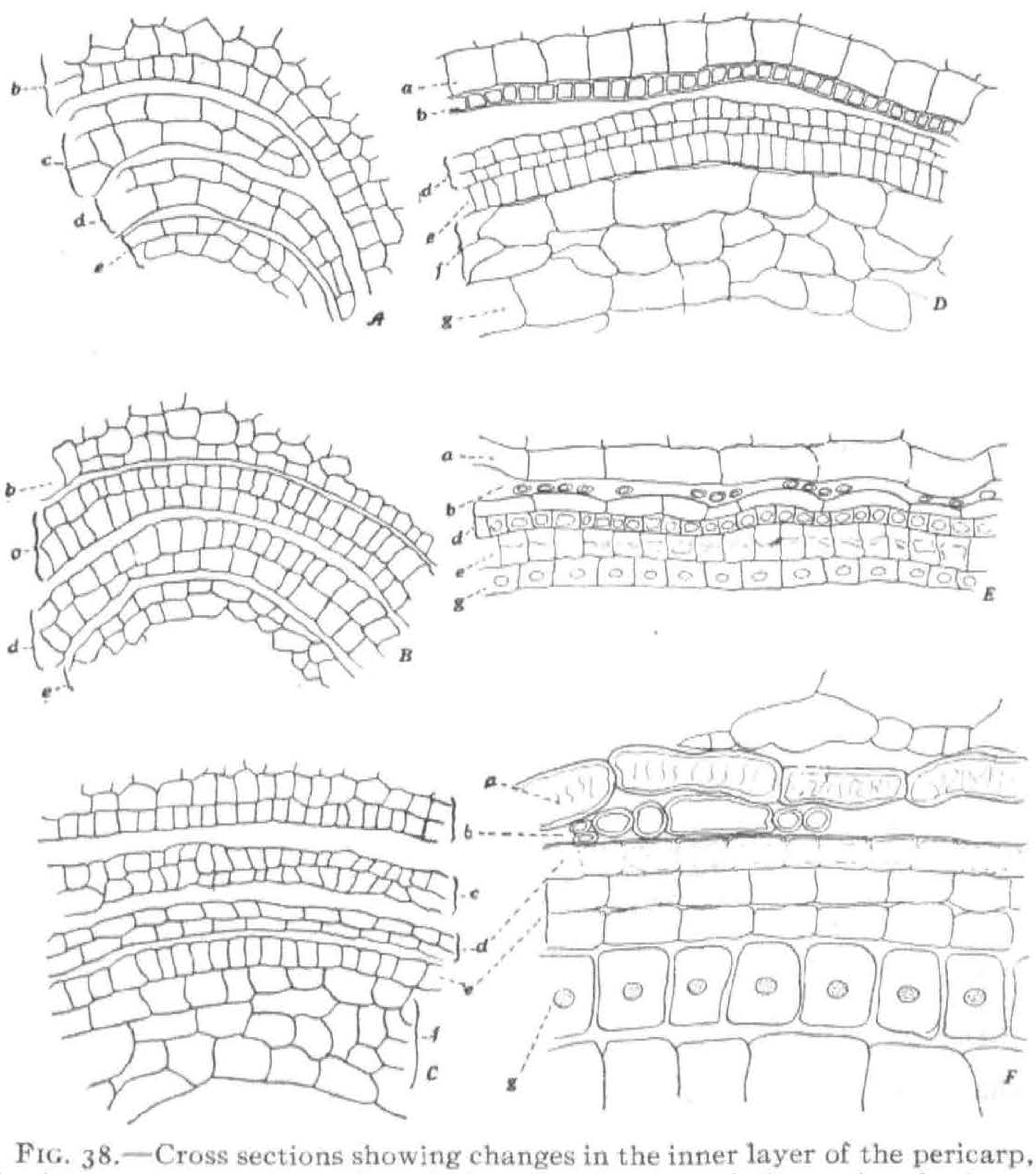


FIG. 38.—Cross sections showing changes in the inner layer of the pericarp, the integuments and nucellus during the ripening of the grain of wheat. *a*, chlorophyll layer of pericarp; *b*, inner epidermis of pericarp; *c*, outer integument; *d*, inner integument; *e*, epidermis of nucellus; *f*, cells of the nucellus; *g*, aleurone layer. (*After Percival.*)

two layers each (Fig. 38). In the ripening process, the outer integument is entirely absorbed, so that in the mature grain the testa consists of two rows of cells, belonging to the inner integument. The walls are slightly lignified.

The coloring matter of the grain is found in the inner layer of the testa. It is of two kinds, pale yellow and orange yellow. The proportions of these colors determine whether the wheat is white, yellow, or red.

Brown found in *Triticum*, as well as in *Avena*, *Secale*, and *Hordeum*, that the semi-permeability of the grain coats is localized in the testa. It is very probable that the epidermal membrane of the nucellus also has semi-permeable properties.

Nucellus (perisperm).—The epidermis of the nucellus surrounds the aleurone layer. It is the only remaining portion of the nucellar tissue, which was comparatively large in the undeveloped ovule. The mature nucellus consists of cells with strongly thickened walls, and with indistinct cavities. It is possible that in some cases the nucellus is completely absorbed, and hence wanting in the mature grain.

Endosperm.—The endosperm consists of two portions, starchy or floury endosperm, and aleurone layer. The endosperm constitutes about 92 per cent. of the grain's volume. The cereals are cultivated chiefly for the food material stored in the grain. In all of them, the bulk of this food is found in the endosperm. The chief food materials stored in the endosperm of grains are starch and proteins. The germinating embryo makes use of these foods in the first few days of its growth, or until its roots are taking substances from the soil, and the young leaves are manufacturing food, or, in other words, until the young plant has established its independence.

Aleurone Layer.—This is a single layer of large cells immediately within the nucellus. The cells are rather uniformly square or rectangular when viewed in transverse or longitudinal section, but irregular in shape when viewed perpendicular to the surface. They are stored largely with aleurone grains. This layer is often erroneously called the

gluten layer. The term "gluten" is only properly applied to the principal protein found in the starchy endosperm, and should not be used in connection with the aleurone layer.

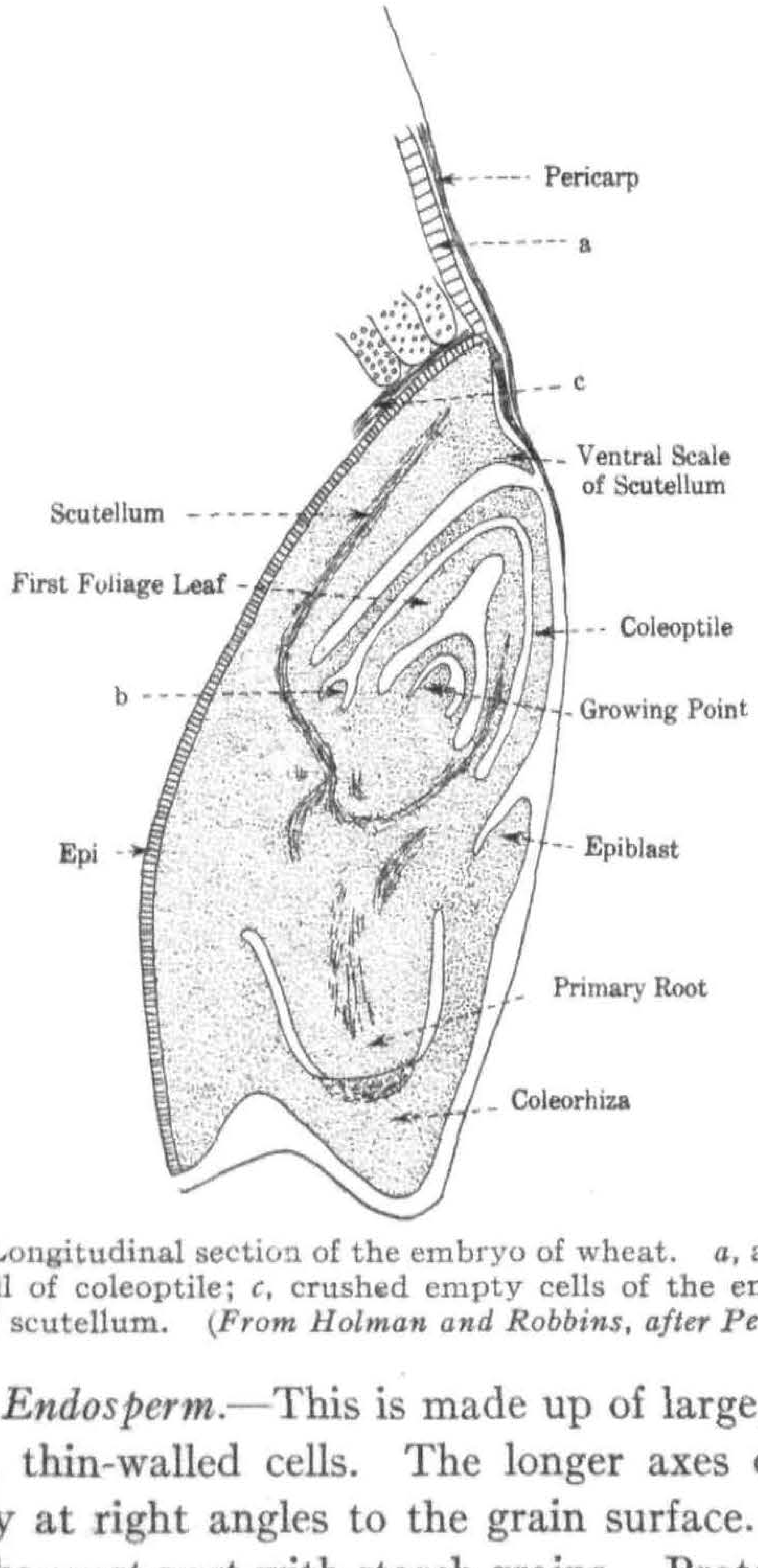


FIG. 39.—Longitudinal section of the embryo of wheat. *a*, aleurone layer; *b*, bud in axil of coleoptile; *c*, crushed empty cells of the endosperm; *epi*, epithelium of scutellum. (*From Holman and Robbins, after Percival.*)

Starchy Endosperm.—This is made up of large, somewhat elongated, thin-walled cells. The longer axes of the cells are usually at right angles to the grain surface. They are filled for the most part with starch grains. Protein granules may be seen among the starch grains by appropriate staining. Most, if not all, of the wheat starch and all of the

gluten occur in this part of the endosperm. The percentage of gluten increases from the center outward; those cells next to the aleurone layer contain the largest amount.

Embryo.—A median lengthwise section of the grain of wheat shows well the structure of the embryo (Fig. 39). The *seminal roots* point toward the micropylar end. They usually consist of a primary rootlet with two pairs of laterals. A fifth lateral rootlet and a third pair may sometimes be formed later, but they are rarely observed in the resting embryo. The primary root and two lowest pairs are surrounded by the *root sheath* or *coleorhiza*. A very short stem, the *hypocotyl*, is between the primary root and the growing point of the shoot. In other words, the hypocotyl terminates at the anterior end in a stem *growing point* and at the posterior end it is prolonged into the *primary root*. There are several immature *foliage leaves* surrounding the growing point and attached to the upper end of the hypocotyl. The growing point and foliage leaves are surrounded by a leaf sheath, the *coleoptile* or *pileole*. At the point where the root sheath merges into hypocotyledonary tissue, there is a small projection, the *epiblast*, a structure devoid of vascular tissue. Lying next to the endosperm is a specialized structure, the *scutellum*, which is attached to the hypocotyl. It has been suggested that the scutellum and epiblast represent two cotyledons, one of which (scutellum) is highly modified, the other (epiblast) suppressed.

We are all familiar with the seedlings of bean or squash. In these, there are two cotyledons (seed leaves) which are brought above ground and function for a while as green leaves. Plants with two cotyledons are said to be dicotyledonous. The scutellum of grasses is regarded as a cotyledon, morphologically. Plants like grasses, sedges, rushes, lilies, etc., which have one cotyledon are said to be *monocotyledon-*

ous. If the epiblast represents a rudimentary second cotyledon, as its position on the embryo would seem to indicate, it stands as evidence of the fact that monocotyledonous plants had dicotyledonous ancestry. Rudimentary structures are a great aid in tracing the racial history of all organisms.

The scutellum remains in the seed during germination, serving in the absorption of and transfer of food from the endosperm to the growing regions. The outermost layer of the scutellum, where it adjoins the endosperm, is a *columnar epithelium.* It is probably this layer which secretes the enzymes through the action of which the starches and proteins in the endosperm are rendered soluble (digested), and which in a soluble form, are enabled to pass from cell to cell to the tissues in the growing points.

The embryo is rich in fat, mineral matter and protein, and contains considerable quantities of soluble carbohydrates, but probably no or very little starch. About one-sixth of the embryo is fat and one-third protein, the two constituting about one-half of its weight.

Bran Layer.—The bran of wheat includes the three outer layers of tissue, viz., pericarp, testa, and nucellus. The pericarp constitutes the largest proportion of the bran and consists largely of mineral and lignified material. The protein content of the bran is due to aleurone cells and starch cells which adhere to bran layers in the milling process.

Commercially speaking, bran consists of the scale-like, flaky outside covering which is removed from the wheat in the milling process. It ordinarily contains, in addition to the pericarp, testa, and nucellus, all or part of the aleurone layer and some starchy endosperm which may adhere to it.

Wheat bran varies considerably in chemical composition, and hence in feeding value, according to the kind of wheat used and the milling process employed in grinding it. It

may contain as low as 14 per cent. and as high as 18 per cent crude protein, with an average of about 16 per cent.

Protein of Wheat.—According to analyses of American wheats compiled in 1890, the protein (nitrogen × 6.25) varies from 8.1 per cent. to 17.2 per cent., with an average of 11.9 per cent. This was in samples containing 10.5 per cent. water, thus making the protein 13.3 per cent. of the dry matter of the grain.

The following five wheat proteins have been recognized: *globulin*, *albumin*, *proteose*, *gliadin*, and *glutenin*. The latter two proteins compose *gluten*. Gliadin is the sticky substance in gluten.

As a general rule, grains that have a marked glutenous or horny or flinty appearance are higher in protein than those that have a starchy or dull appearance. However, it is known that a given variety may produce a grain that is hard and rich in gluten; or one that is soft and low in gluten, depending on the environmental factors. But it seems true, nevertheless, that the term "quality" refers to both the physical characteristic and chemical composition of the grain.

Relative Proportions of the Parts of the Grain.—

1. *Bran* (pericarp, testa, nucellus), 8 to 9 per cent.
2. *Aleurone layer*, 3 to 4 per cent.
3. *Starchy* or *floury endosperm*, 82 to 86 per cent.
4. *Embryo* or *germ*, about 6 per cent.

"Hard" and "Soft" Wheats.—A "hard" wheat is one with a horny or flinty texture, and quite high in protein. Hard wheats, as a result of their high gluten content, make a "strong" flour, which is adapted for making light bread. A "soft" wheat is more easily crushed than a hard wheat, has a starchy or dull appearance, and is relatively rich in starch. The "soft" wheats have been regarded with favor for the making of bread and pastry flours. However, the flour from soft wheats is said to be "weak," that is incapable of making

a large heavy loaf. At first there was much opposition to hard wheats, because of difficulties in milling and baking. In recent years, however, this opposition has been largely overcome.

There are three classes of hard wheats in this country: (1) hard spring wheat, (2) hard winter wheat, and (3) durum wheat. The principal hard spring wheats are Fife and Bluestem. Turkey and Kharkov are the chief hard winter wheats, and Kubanka the most important durum wheat. On account of its highly glutenous character, durum is used extensively in the manufacture of macaroni and vermicelli. The flour of this hard, glutenous wheat is being mixed with that from the softer wheats, and the result is a flour of excellent bread-making qualities.

Much emphasis has been placed upon the great influence of climate upon the composition, hardness and quality of wheat. In fact, it is claimed that the soil has little or no effect upon these characters. In general, a hot, dry climate produces a fine-stemmed plant the grain of which is hard, glassy and rich in nitrogen, while a cool, moist climate produces a coarser-stemmed plant the grain of which is relatively soft, mealy and poor in nitrogen. Headden, however, has been able to produce starchy and flinty kernels at will in the same variety growing under identical climatic conditions, by controlling the ratio of nitrogen to potassium. An abundance of nitrates produced a flinty grain, while a scarcity of nitrates in proportion to potash gave a starchy, mealy grain. This work establishes the fact that the soil, as well as the climate, is a factor in determining the quality of wheat.

Milling of Wheat.—The wheat is first thoroughly cleaned and scoured to remove sticks, straw, fine dust particles, and hairs of the brush. It is then slightly moistened with water, in order to prevent the pericarp from grinding up fine. This

is known as *tempering*. Then comes the process of *breaking*. This consists in removing the bran coats and embryo from the endosperm, and the gradual reduction of the latter to finer and finer particles. In this process the grain is passed between successive pairs of corrugated iron rolls. The product of each set of rolls is sifted, and the particles are graded according to size, the coarser particles passing on to the next set of rolls. Finally, the pericarp layers are completely separated from the adhering layers of aleurone and starchy endosperm cells. The finely ground parts of the endosperm are sifted and bolted. The material that will pass through fine silk bolting cloth is called *flour*. The larger and coarser particles that remain behind are known as *middlings*. The middlings are then freed of particles of bran, *i.e.*, *purified*, and passed between several sets of smooth rolls; the product of each set of rolls is taken to a machine which separates out the fine flour. The number of grades of flour, and of other products, will depend upon the number of sets of rolls, and the mesh of the bolts to which the grain and its ground products are subjected. Mills differ much in the grades of material turned out.

Kinds of Flour.—There are three general sorts of flour: *graham*, *entire wheat*, and *patent* or *straight bread flour*. "*Graham flour*" is the product obtained by grinding the entire kernel of wheat. Its name is after that of Sylvester Graham (1794–1851), a physician and writer on dietetics. "*Entire wheat flour*" contains about one-half of the coarse bran. In patent grades of flour all of the bran is removed. There are several grades of patent flour, but the most common one on the market is the "*straight*" or "*standard patent*." It is usually a combination of the so-called "first patent," "second patent," and "first clear" flours. About 72 to 75 per cent. of the total wheat is recovered as "straight" or "standard patent" flour. It is composed of floury endo-

sperm alone. The ordinary bread flours belong to this grade. Other products of the milling process are known as "second clear" flour, used for low-grade bread, "red dog" also used for low-grade bread or for cattle feed, and "shorts," "middlings" and "bran." About 25 per cent. of the grain is returned as shorts, middlings and bran. The composition of these varies somewhat with the milling process.

Germination of Wheat.—The time required for germination depends upon external conditions. It has been determined experimentally that wheat, as well as oats, barley and rye, will germinate at the temperature of melting ice. Freshly harvested wheat gives the highest percentage germination at a temperature of approximately 59°F., whereas the optimum temperature for wheat that has been in storage for a number of months is between 65° and 75°F.

Three germinating stages in wheat are shown in Fig. 3. The primary root is the first to appear. It ruptures the coleorhiza which remains as a collar about the root where it breaks through the grain coats. Often two lateral roots appear arising from the sides of the hypocotyl. Another pair of rootlets may make its appearance in a few days, which develops on the hypocotyl immediately above the first pair. And, a sixth rootlet, and third pair may rarely be observed somewhat later. The growing point elongates, the first young leaf being enclosed by the leaf sheath or coleoptile, a closed and pointed organ. The coleoptile protects the growing point and serves as a boring organ. The coleoptile of wheat has the greatest soil-penetrating ability of the common cereals. Its length varies with the variety and with the depth of seeding. The closed end of the coleoptile is broken by the first foliage leaf. The cotyledon (scutellum) is left beneath the ground.

There has been much discussion concerning the vitality of wheat grain, and frequent claims are made that grains from

ancient tombs still possess the capacity for germination. However, all tests made with grains of wheat from ancient tombs have shown that such grains are dead. Percival states that "modern wheat grains appropriately stained have sometimes been fraudently mixed with wheat taken from ancient

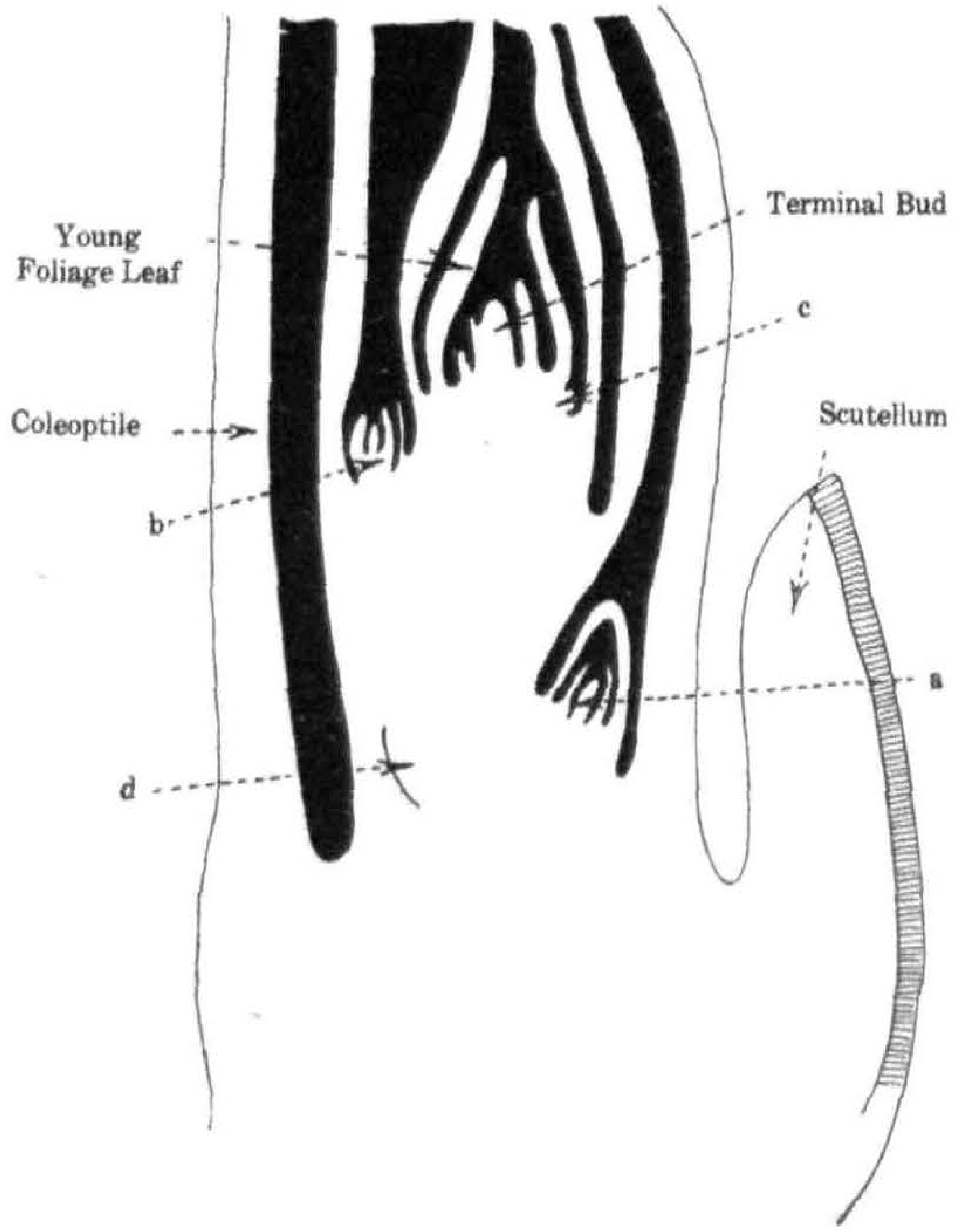


FIG. 40.—Longitudinal section through a young wheat plant 14 days old. *a*, bud in the axil of the coleoptile; *b*, bud in the axil of the first foliage leaf; *c*, bud in the axil of the second foliage leaf; *d*, adventitious root. (*From Holman and Robbins, after Percival.*)

vases, the whole being sold to the credulous tourist as 'mummy wheat,' or introduced into mummy cases, or placed within the wrappings of mummies."

It has been demonstrated that under ordinary storage conditions, wheat has its germinating capacity greatly reduced or entirely destroyed in 8 or 10 years.

Repeated Germination.—The grains of wheat, and the seeds of a number of other agricultural plants, are capable of repeated germination. A grain may start to sprout, the process be stopped by dryness, and sprout again if moisture is available. Beal germinated wheat and buckwheat six times, each time allowing the root and stem to grow to the length of the grain, with the following results:

REPEATED GERMINATION

Kind of seed	Per cent. germinated					
	1st	2d	3d	4th	5th	6th
Schumacher wheat......	100	100	90	87	67	8
Clawson wheat.........	100	100	97	98	84	38
Buckwheat.............	100	100	100	98	65	39

Classification of the Types of Wheat.—Hackel divides the genus *Triticum* into two sections, *Aegilops* and *Sitopyros*.

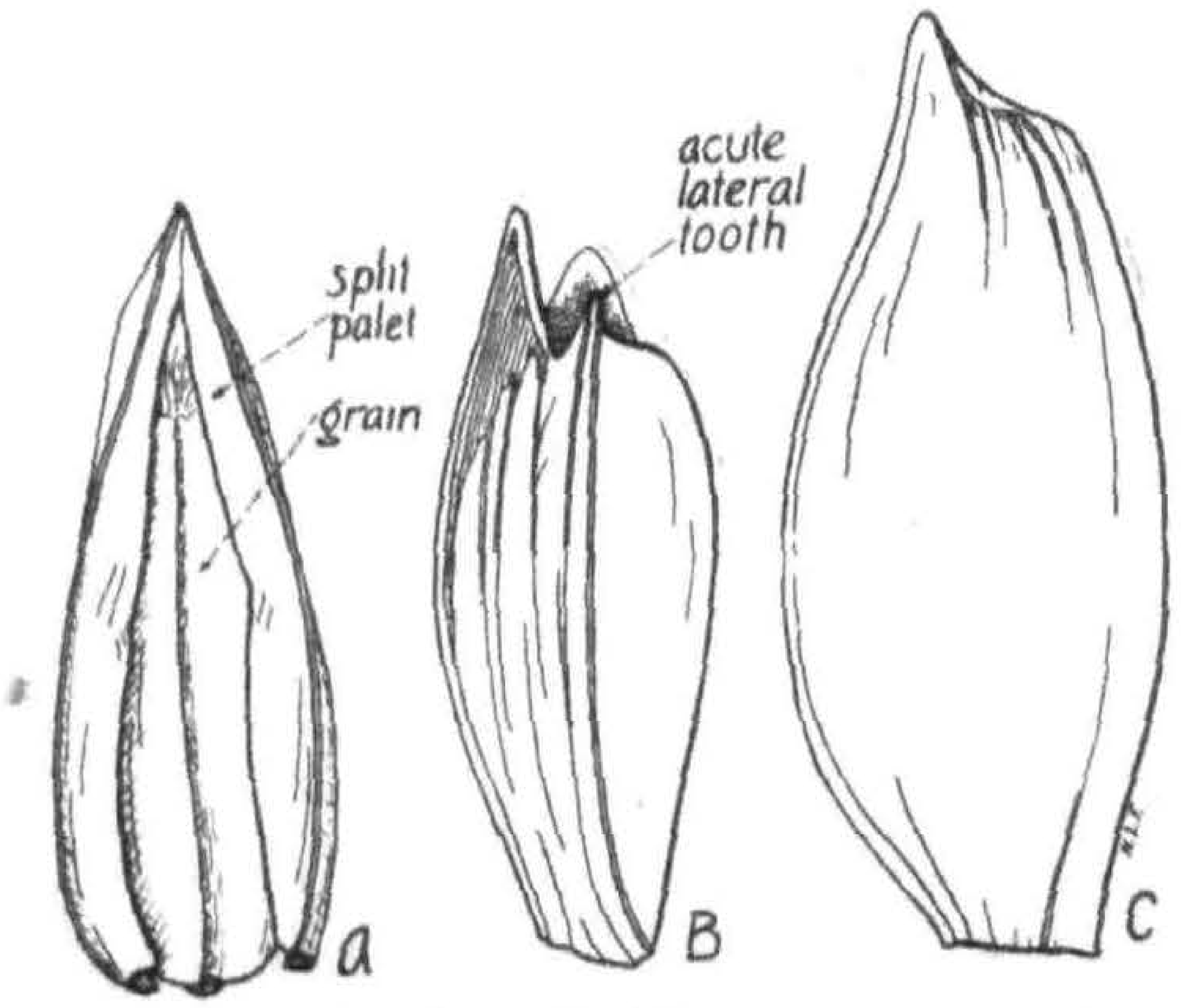


FIG. 41.—*A*, split palet of einkorn (Triticum monococcum) surrounding the grain; *B*, glume of einkorn; *C*, glume of club wheat (T. compactum). × 5.

In the first, the glumes are flat or rounded on the back; in the second, keeled. *T. ovata* is the principal species in the

Aegilops section. It occurs in southern Europe, and as far east as Turkestan in Asia. The cultivated wheats belong to the Sitopyros section.

Key to Economic Types of Wheat

Spikelets two flowered, one sterile, one fertile; terminal spikelet aborted; lateral teeth of glumes acute (Fig. 41); palet dividing lengthwise when mature. *T. monococcum* (einkorn).

Spikelets more than two-flowered, two or more fertile; terminal spikelet developed; lateral teeth of glumes obtuse; palet remaining entire at maturity.

- Glumes as long or usually longer than lemma; palet about two-thirds as long as lemma. *T. polonicum* (Polish wheat).
- Glumes shorter than lemme; palet nearly as long as lemma.
  - Rachis brittle, articulated, breaking at nodes when threshed, the segments remaining attached to spikelets; spikelets two-grained (sometimes three in spelt).
    - Spikelets not set thickly on stem; arched on inner side; adhering portion of rachis thick, blunt; stem above with central canal. *T. spelta* (spelt).
    - Spikelets set thickly on stem; flattened on inner side; adhering portion of rachis slender, pointed, stem above, with exception of narrow canal, filled with pith. *T. dicoccum* (emmer).
  - Rachis tenacious, not articulated, remaining entire in threshing, spikelets usually more than two-grained.
    - Empty glumes sharply and broadly keeled to the base; lemma bearded; straw usually solid.
      - Spike with sides parallel or nearly so; glumes with a bloom, usually glabrous; grain very hard, horny, long. *T. durum* (durum wheat).
      - Spike short, crowded, long-ovate; glumes usually pubescent; grain short, blunt and softer than that of *T. durum*. *T. turgidum* (Poulard wheat).
    - Empty glumes keeled in upper half; rounded below (sometimes slightly keeled in lower half); lemma sometimes bearded; straw hollow.
      - Spikes very short (rarely over 2 inches); very compact or crowded; thicker at apex than center or base; grains small, short. *T. compactum* (club wheat).
      - Spikes longer than 2 inches, open; sides usually parallel or nearly so. *T. æstivum* (common bread wheat).

The types of wheat fall into two natural groups, as to attachment of lemma and palet to grain, as follows:

1. "*Naked wheats*," in which the grain comes free from the lemma and palet, and the rachis is tenacious (*T. durum, turgidum, compactum, æstivum*, and *polonicum*).

2. "*Spelt wheats*," in which the grain remains attached

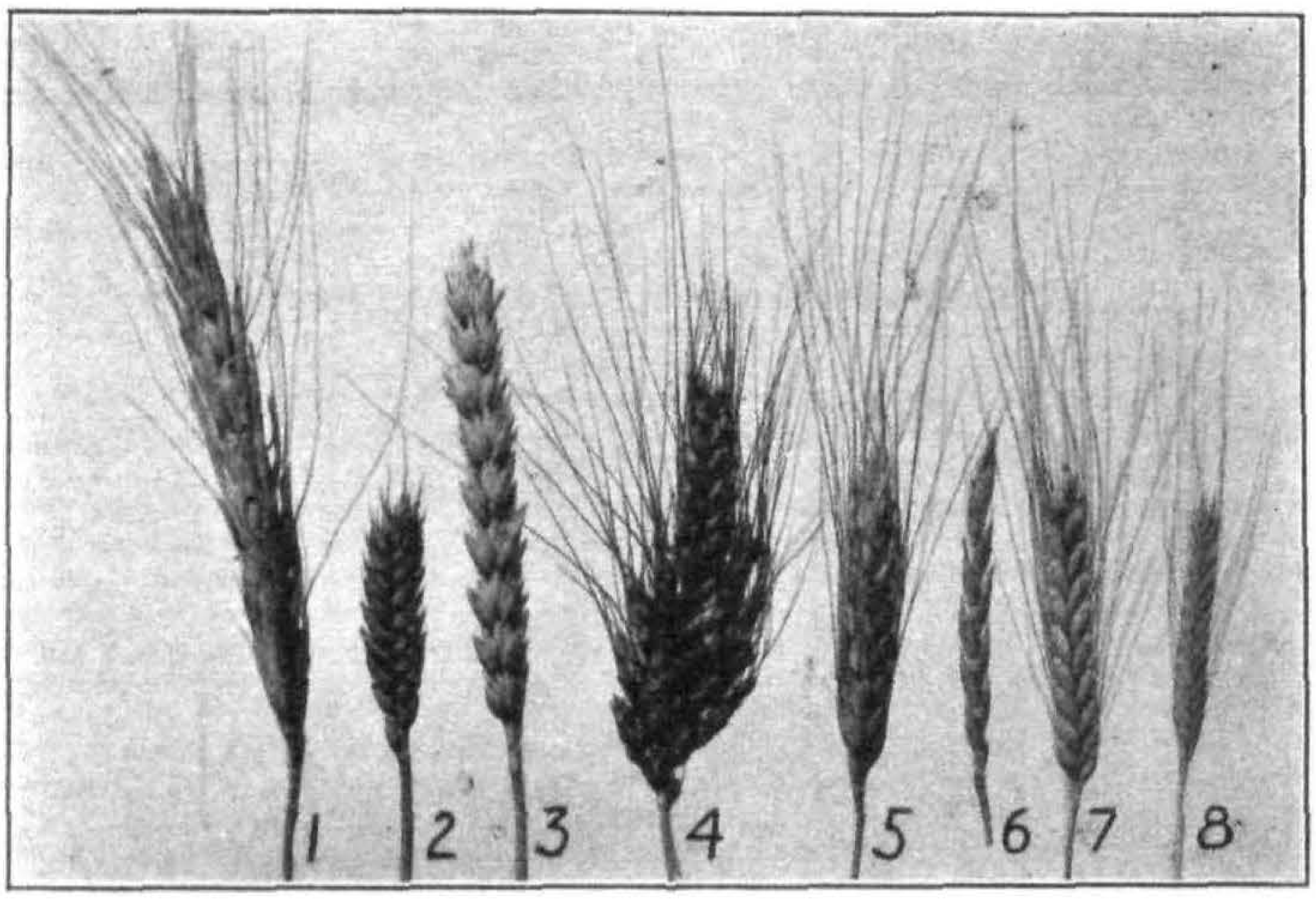


FIG. 42.—Spikes of the types of wheat. 1, Polish wheat (Triticum polonicum); 2, club wheat (T. compactum); 3, common bread wheat (T. æstivum); 4, Poulard wheat (T. turgidum); 5, durum wheat (T. durum); 6, spelt (T. spelta); 7, emmer (T. dicoccum); 8, einkorn (T. monococcum).

to the lemma and palet, and the rachis is fragile (*T. monococcum, dicoccum*, and *spelta*).

Beyerinck has succeeded in producing crosses of einkorn with *dicoccum*, none of which were fertile, however. Aaronsohn says that *T. polonicum* hybridizes with the other species, *T. æstivum* and *T. monococcum*, but the offspring are not fertile.

T. monococcum (einkorn) is a small-headed species of no economic importance in this country. It is cultivated to some extent in Spain, Germany, and Switzerland. Grains in the ear have been found in the remains near the

homes of Swiss lake-dwellers of the Stone Age. It is a native of Asia Minor. *Triticum ægilopoides* is considered to be the wild form of our cultivated einkorn. This wild species is divided into the two subspecies: *T. thaoudar* and *T. boeoticum*. In the first, only the lower flower is fertile, as a rule, but both bear awns, while in *boeoticum* only the lower flower is fertile and awn-bearing. There is a difference of opinion as to which of these stem forms is nearest to our cultivated einkorn. *T. ægilopoides* differs from cultivated forms of einkorn in that its spikes are more fragile, and the grains smaller and lighter in color.

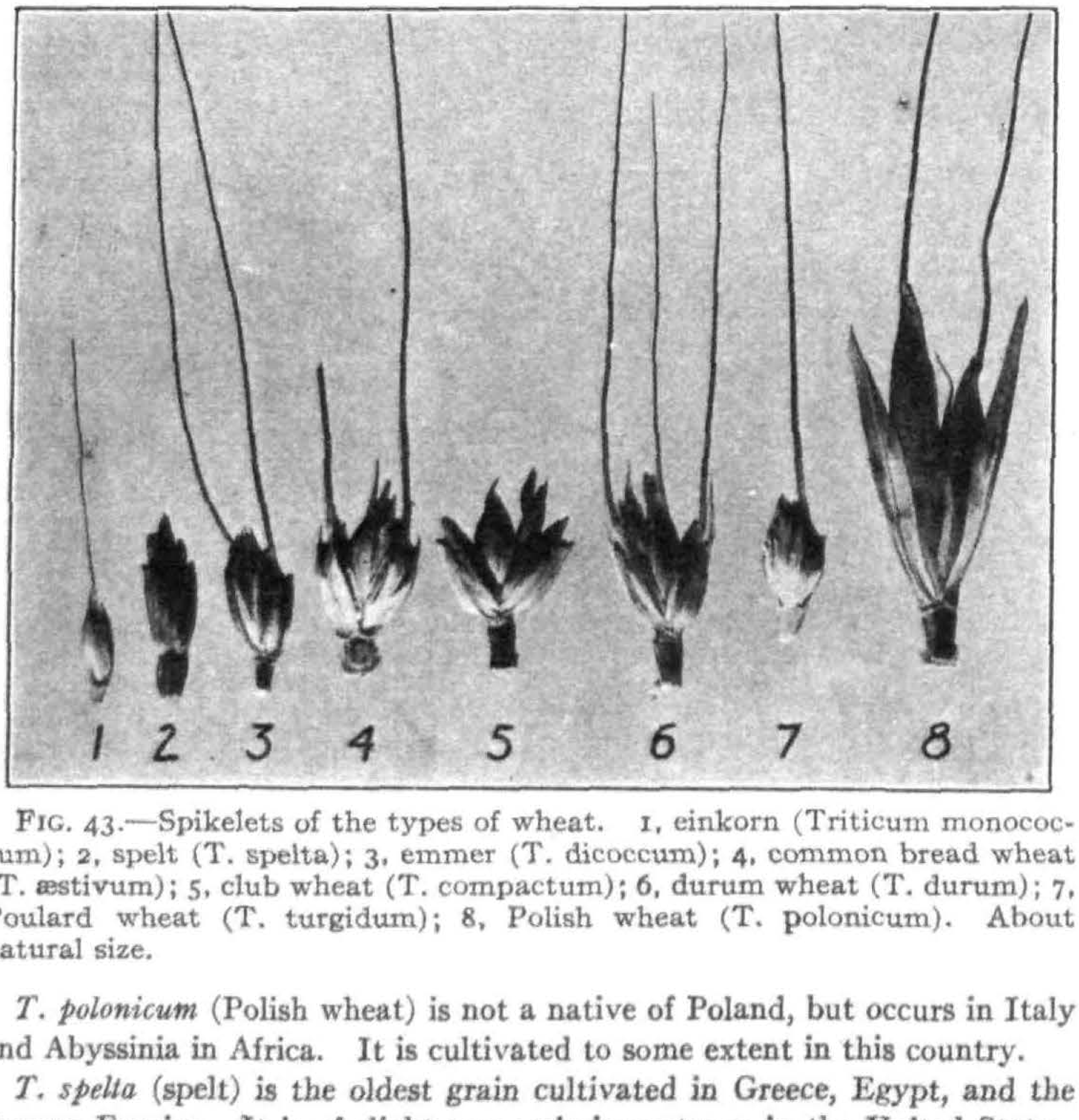


FIG. 43.—Spikelets of the types of wheat. 1, einkorn (Triticum monococcum); 2, spelt (T. spelta); 3, emmer (T. dicoccum); 4, common bread wheat (T. æstivum); 5, club wheat (T. compactum); 6, durum wheat (T. durum); 7, Poulard wheat (T. turgidum); 8, Polish wheat (T. polonicum). About natural size.

T. polonicum (Polish wheat) is not a native of Poland, but occurs in Italy and Abyssinia in Africa. It is cultivated to some extent in this country.

T. spelta (spelt) is the oldest grain cultivated in Greece, Egypt, and the Roman Empire. It is of slight economic importance in the United States.

T. dicoccum (emmer) is of some economic importance in this country, especially in the Western States. It is used as a feed for live stock, and to some extent in the manufacture of breakfast food.

T. durum (durum) varieties are also known as "goose," "wild goose," and "macaroni" wheats. They are hard wheats, particularly adapted

to the arid regions, where they are better yielders than *æstivum* wheats. Durum wheat resembles barley. Its heads are the longest among the wheats. The grains are hard, glassy, often translucent and rather large. Durum wheats are used extensively in the manufacture of macaroni, spaghetti and semolina.

T. turgidum (Poulard wheat) is of little consequence in this country. The spikes are quadrangular or rectangular in cross-section. There is a tendency to form branching spikes, as in Alaskan and Seven-headed or Egyptian varieties. Such varieties also go under such common names as Stoner, Miracle, Eldorado, Jerusalem, Many-headed, Many-spiked, Wild Goose, etc.

T. compactum (club wheat) varieties are said to be adapted to the Pacific Coast and Rocky Mountain States. In club wheats, the spikes are only two or three times as long as broad, and typically broader at the top than at the base, thus appearing somewhat club-shaped. The joints of the rachis are very short, so that the spikelets are crowded and often stand outright.

T. æstivum (common wheat).—The bread wheats of the world are largely varieties of *æstivum*.

Origin of Wheat.—A few years ago, Aaronsohn brought from Syria a wild emmer which was named by Koernicke *Triticum dicoccum dicoccoides* (*T. hermonis* Cook) (Fig. 44). Later, in an expedition in Upper Galilee to the north of Lake Tiberias, he found this wild emmer again, and, on Mount Hermon near the village of Arny, he found it very common and in a variety of forms. This was at an altitude of 1,500 to 2,000 meters. Chodat concludes that wheat is indigenous to Syria. He considers that *T. dicoccum dicoccoides*, a form with a fragile rachis, is the primitive type of wheat. It is interesting to note that the grains of this "wild wheat" are not inferior in weight or size to those of the best cultivated varieties.

It is well agreed that the prototype of our cultivated wheats, whatever it is, is one with a fragile rachis. The rigid rachis is considered to be developed by man. It is known that the wheats cultivated in most ancient times were those with fragile rachises, such as emmer. Furthermore, all genera and species related to wheat, such as Aegilops and Agropyron, etc., have a fragile rachis. The only cultivated

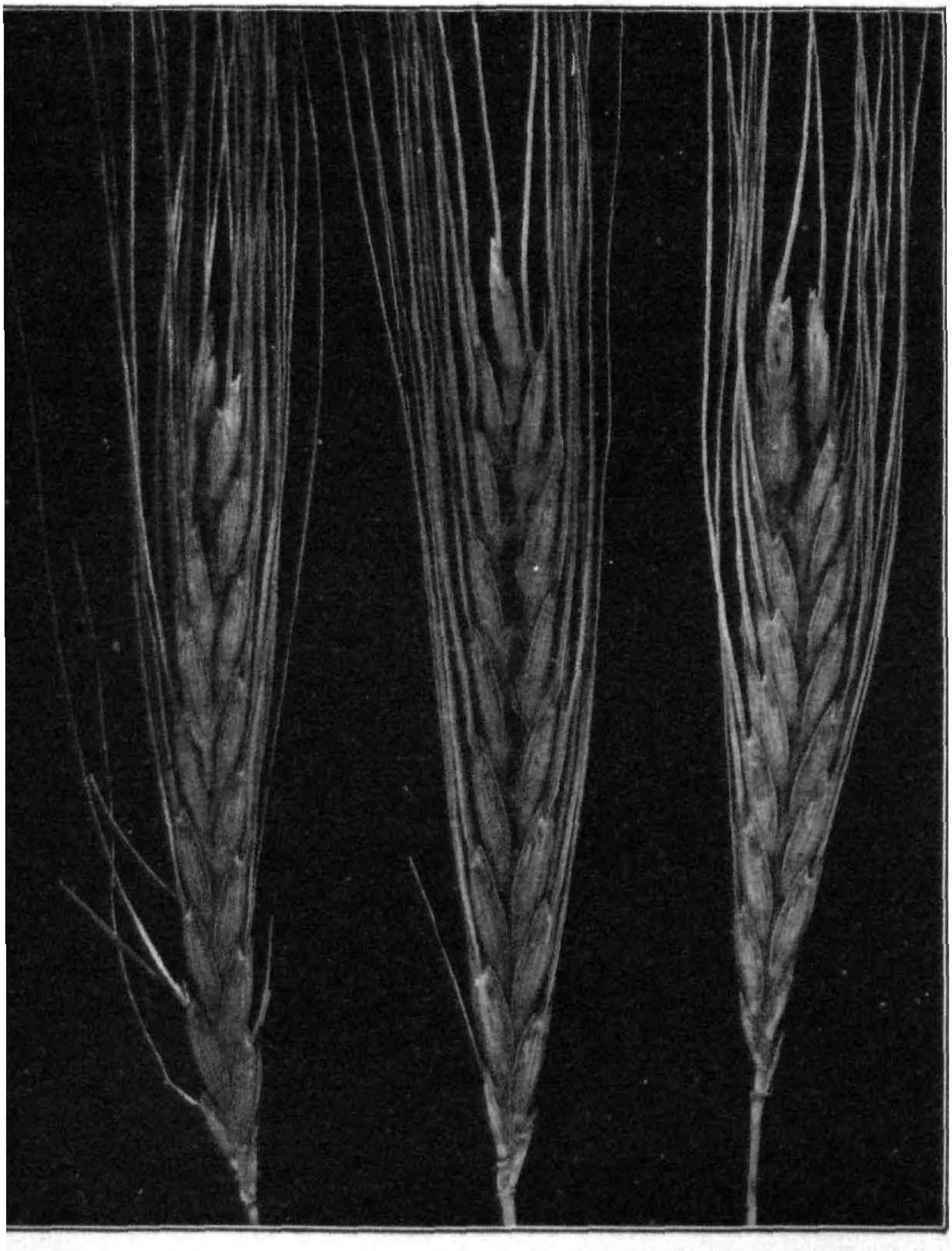


FIG. 44.—Wild emmer of Palestine (Triticum dicoccum dicoccoides), grown in experimental plat at Bard, California. (*Cook, U. S. Dept. of Agr.*)

wheats of today with brittle rachises are einkorn, emmer, and spelt.

It is observed that cross-pollination is more prevalent in Aaronsohn's primitive wheat than in cultivated forms. This may be due to the fact that it grows in a warm, dry climate, while most cultivated wheats belong to northern climates, where cold or wet weather prevents flower opening. In India, it has been observed that cross-pollination in wheat is more frequent than in northern climates.

In the wild wheat of Palestine, the kernels are normally retained by the spikelet. It differs also from domesticated wheat in the order of maturity of the spikelets. In domesticated wheat, the first spikelets to develop flowers are those near the middle of the head, while in the primitive wheat the terminal spikelets are the first ones. Primitive wheat also shows some indications of sexual dimorphism. Some plants have been observed to bear protogynous, others protandrous, flowers. The spikelets of this wild form never mature more than two grains (Fig. 45), and those of the same spikelet are unequal in size. The smaller grain is borne by the lower flower in the spikelet; this flower has the longer awn too.

FIG. 45.—Spikelet of wild emmer (Triticum dicoccum dicoccoides). × 2½.

A. Schulz thinks that many, but not all, of the primitive wheat individuals found by Aaronsohn are hybrids between *T. ægilopoides thaoudar* and *dicoccoides*. The origin of the different types of cultivated wheats, as given by Schulz, is shown in the following:

1. *Einkorn series*, of which *T. ægilopoides* is the prototype.

2. *Emmer series*, of which *T. dicoccoides* is the stem form. From this have come *dicoccum*, *durum*, *turgidum*, and *polonicum*.

3. *Spelt series*, of which the stem form is unknown. From this have come *spelta*, *compactum*, *æstivum*, and *capitatum*.

Environmental Relations.—Wheat is grown under a wide range of temperature conditions. Some varieties come to maturity and yield well as far as 64° N. latitude in Norway, and up to 8,000 feet elevation in the Central Rocky Mountains. In this last-mentioned section wheat will yield a crop, except in unusual years, where the mean temperature for the year is not below 38°F., and that for the summer season is not below 58°F. Winter wheats are able to resist low temperatures for longer periods than spring wheats.

Plants differ widely in their water economy. Some require much more water than others to produce a unit of dry matter. The *water requirement* of a plant is defined as the number of units of water absorbed by the plant in the production of a unit of dry matter. The following data are taken from Briggs and Shantz:

WATER-REQUIREMENT DETERMINATIONS AT AKRON, COLORADO, 1911, 1912, AND 1913, BASED ON THE PRODUCTION OF DRY MATTER

Plant	Mean of genus
Proso	293
Millet	310
Sorghum	322
Corn	368
Wheat	513
Barley	534
Buckwheat	578
Oats	597
Rye	685
Beet, sugar	397
Potato	636
Pea, Canada field	788
Alfalfa	831

If the water requirement of proso millet is regarded as 1, the water requirement for the following crops is as follows: millet 1.06; sorghum 1.10; corn, 1.26; wheat 1.76; barley 1.83; oats 2.04; rye, 2.34; rice, 2.42.

The water requirement of a plant is dependent upon a number of conditions, chief of which is the fertility of the soil. The water requirement is greater in an infertile than in a fertile soil. The application of fertilizers may increase the total amount of water taken in by the plant, due to increased plant growth, but the requirement per unit of dry matter is lowered.

The effect of climate and soil on the composition of the grain has been discussed.

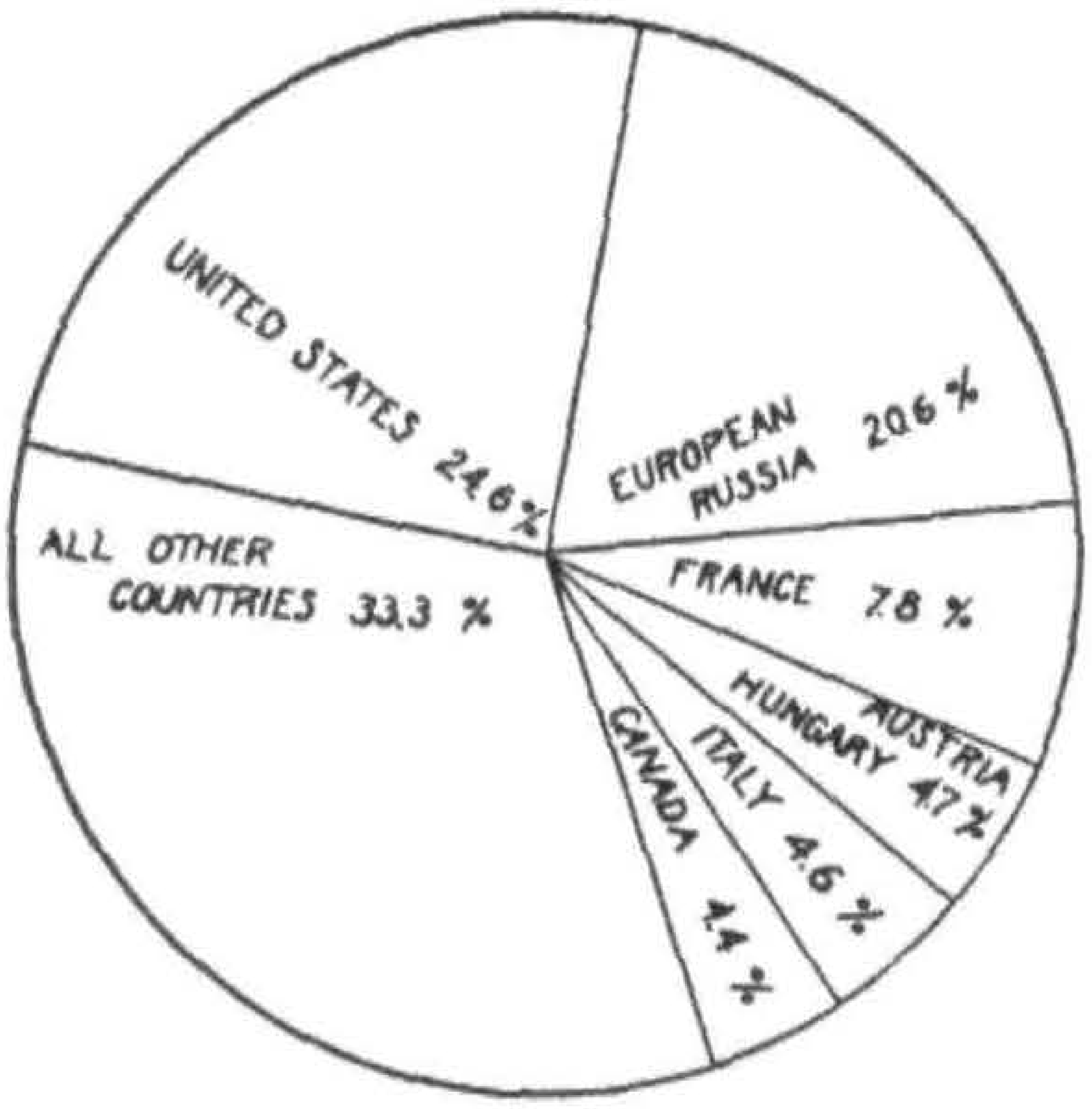


FIG. 46.—Diagram showing the percentage of the world's wheat crop produced by the different countries in 1915.

Uses of Wheat.—By far the largest proportion of the world's supply of flour is made from wheat. As already stated, the hard wheats, particularly durum varieties, are used extensively in the manufacture of macaroni and allied products. In the *manufacture of macaroni*, the wheat is first ground into a course product known as "*semolina.*" It is freed then of any adhering particles of fine flour and bran. The semolina is mixed with about 30 per cent. of water, worked into a stiff dough, and given a thorough kneeding. The dough is then forced through a press, from which it issues in long hollow tubes. These tubes of moist

dough are then carefully dried in a manner to prevent them from becoming too brittle or sour. Vermicelli and spaghetti are also made from semolina and water, but dies of different form are used, and drying is done on frames. Many sorts of breakfast foods are made from wheat. A very recent product is puffed wheat, in the preparation of which the kernels are expanded by heating to a high temperature under pressure, and then the pressure is suddenly released. The whole grain, screenings, bran, shorts, middlings and "red dog" are fed to animals. Sometimes wheat is sown with vetch and the two together used for silage purposes. Wheat, as well as other cereals, finds use in the manufacture of whiskey. It is employed also in the making of weiss-beer malt.

References

AARONSOHN, A., and SCHWEINFURTH, G.: Die Auffindung des wilden Emmers (Triticum dicoccum) in Nord Palästina. Altneuland Monatsschr. für die wirtschaftliche Erschliessung Palästinas, Berlin, Nos. 7–8, 213–220, 1906.

AARONSOHN, AARON: Agricultural and Botanical Exploration in Palestine: Wild Prototypes of Wheat and Other Cereals in Palestine. U. S. Dept. Agr. Bur. Plant Ind. Bull. 180: 36–52, 1910.

BEIJERINCK, M. W.: Über den Weizenbastard Triticum monococcum ♀? Triticum dicoccum ♂. Nederlandsch Kruidkundig Archief., ser. 2, T. 4: 189–201, 1886.

BESSEY, C. E.: The Structure of the Wheat Grain. Nebr. Agr. Exp. Sta. Bull. 32: 100–114, 1894.

BLOOMFIELD, L. M.: Contributions to the Life History of the Wheat Plant (T. vulgare). Ann. Rep. Ohio State Acad. Sci., 2: 12–14, 1894.

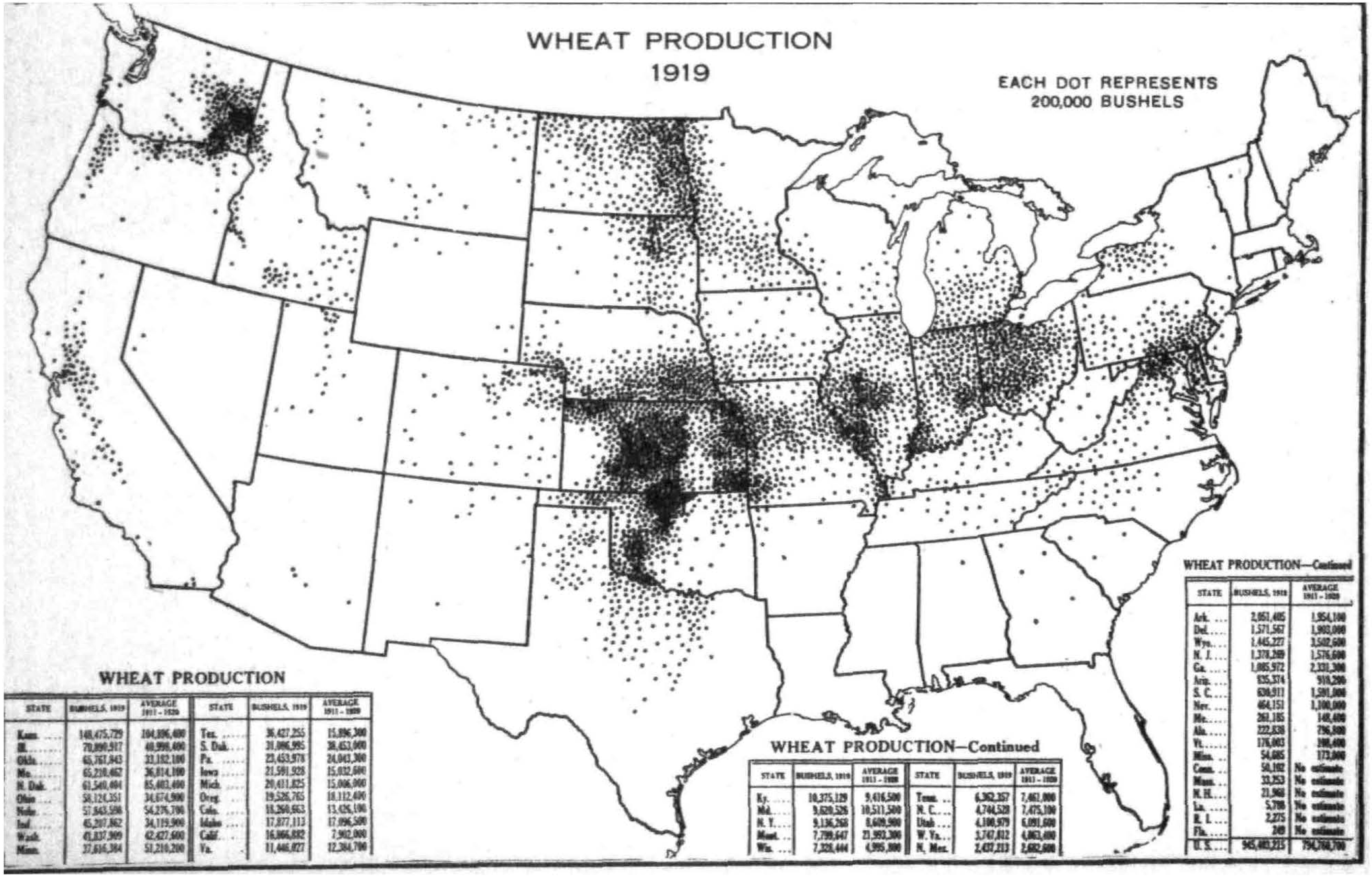
BRENCHLEY, W. E.: On the Strength and Development of the Grain of Wheat (T. vulgare). Ann. Bot., 23: 117–139, 1909.

BRENCHLEY, W. E., and HALL, A. D.: The Development of the Grain of Wheat. Jour. Agr. Sci., 3: 195 217, 1909.

CHODAT, R.: A Grain of Wheat. Pop. Sci. Mo., 82: 33–46, 1913.

CLARK, J. ALLEN, MARTIN, JOHN H., BALL, CARLETON R.: Classification of American Wheat Varieties. U. S. Dept. Agr. Bull. 1074: 1–238, 1922.

COBB, N. A.: Universal Nomenclature of Wheat. N. S. W. Dept. Agr. Misc. Pub. 539, 1905.



WHEAT PRODUCTION

STATE	BUSHELS, 1919	AVERAGE 1911–1920	STATE	BUSHELS, 1919	AVERAGE 1911–1920
Kans.	148,475,729	104,896,400	Tex.	36,427,255	15,896,300
Ill.	70,899,917	40,998,400	S. Dak.	31,096,995	38,453,900
Okla.	65,767,843	33,182,100	Pa.	23,453,978	24,043,300
Mo.	65,210,467	36,814,100	Iowa	21,591,928	15,032,600
N. Dak.	61,540,404	85,403,400	Mich.	20,411,825	15,006,000
Ohio	58,124,351	34,674,900	Oreg.	19,526,765	18,112,400
Nebr.	57,843,598	54,276,700	Colo.	18,260,663	13,426,100
Ind.	45,207,862	34,119,900	Idaho	17,877,113	17,096,500
Wash.	41,837,909	42,427,600	Calif.	16,866,882	7,902,000
Minn.	37,616,384	51,210,200	Va.	11,446,027	12,384,700

WHEAT PRODUCTION—Continued

STATE	BUSHELS, 1919	AVERAGE 1911–1920	STATE	BUSHELS, 1919	AVERAGE 1911–1920
Ky.	10,375,129	9,416,500	Tenn.	6,362,357	7,461,000
Md.	9,620,526	10,511,500	N. C.	4,744,528	7,475,100
N. Y.	9,136,268	8,609,900	Utah	4,100,979	6,091,600
Mont.	7,799,647	21,952,300	W. Va.	3,747,812	4,863,400
Wis.	7,320,444	4,995,000	N. Mex.	2,437,213	2,682,600

WHEAT PRODUCTION—Continued

STATE	BUSHELS, 1919	AVERAGE 1911–1920
Ark.	2,051,405	1,954,100
Del.	1,571,567	1,903,000
Wyo.	1,445,227	3,502,600
N. J.	1,378,269	1,576,600
Ga.	1,085,972	2,331,300
Ariz.	935,374	919,200
S. C.	638,911	1,591,000
Nev.	464,151	1,100,000
Me.	261,185	148,400
Ala.	222,838	796,800
Vt.	176,003	198,400
Miss.	54,685	173,000
Conn.	50,102	No estimate
Mass.	33,253	No estimate
N. H.	21,968	No estimate
La.	5,798	No estimate
R. I.	2,275	No estimate
Fla.	249	No estimate
U. S.	945,403,215	794,768,700

COOK, O. F.: Wild Wheat in Palestine. U. S. Dept. Agr. Bur. Plant Ind. Bull. 274: 1–56, 1913.

DONDLINGER, P. T.: The Book of Wheat. Orange Judd Co., 1908.

ECKERSON, SOPHIA H.: Microchemical Studies in the Progressive Development of the Wheat Plant. Wash. Agr. Exp. Sta. Bull. 139: 1–20, 1917.

ERIKSSON, J.: Beiträge zur Systematik des cultivierten Weizens. Landw. Versuchsstat., 45: 37–135, 1894.

FRUWIRTH, C.: Das Blühen von Weizen und Hafer. Deut. Landw. Presse, 32: 737–739, 747–748, 1905.

GRANTHAM, A. E.: The Tillering of Wheat Science. N. S., 46: 392–394, 1917.

HAYS, WILLET M., and BOSS, ANDREW: Some Botanical Characteristics of Wheat. Minn. Agr. Exp. Sta. Bull. 62: 391–421, 1899.

HEADDEN, W. P.: Yellow-berry in Wheat. Colorado Agr. Exp. Sta. Bull. 205: 1–38, 1915.

KONDO, M.: Studies on Heads of Wheat and Spelt as a Contribution to Exact Classification. Landw. Jahrb., 45: 713–817, 1913.

KRAUSE, ERNST, H. S.: Die Heimat des Spelzes. Naturw. Wchenschr., 25: 412–414, 1910.

LEIGHTY, C. E., and SANDO, W. S.: The Blooming of Wheat Flowers. Unpublished Manuscript from Office of Cereal Investigations, U. S. Dept. Agri., Washington, D. C.

MÖBIUS, F.: Untersuchungen über die Sorteneinteilung bei Triticum vulgare. Inaug. Diss., Giessen, 1913. Druck von F. Stollberg, Merseburg.

OSBORNE, T. B.: The Protein of Wheat Kernel. Carnegie Inst. Washington Pub. 84: 1–119, 1907.

PERCIVAL, JOHN: The Wheat Plant. A Monograph. E. P. Dutton & Co.

SCHULZ, AUGUST: Abstammung und Heimat des Weizens. 39 Jahrsber. Westfäl. Prov. Ver. Wiss. u. Kunst (zu Münster) für 1910–1911, S. 147–152, 1911.

Die Geschichte des Weizens. Ztschr. Naturw., 83: 1–68, 1911.

Die Abstammung des Weizens. Mitt. Naturf. Gesell, Halle, 1: 14–17, 1912.

Die Abstammung des Einkorns (T. monococcum L.). Mitt. Naturf. Gesell. Halle, 2: 12–16, 1913.

Triticum aegilopoides Thaoudar X dicoccoides. Mitt. Naturf. Gesell. Halle, 2: 17–20, 1913.

SCOFIELD, CARL S.: The Algerian Durum Wheats: A classified list, with descriptions. U. S. Dept. Agr. Bur. Plant Ind. Bull. 7: 1–48, 1902.

TEN EYCK, A. M.: The Roots of Plants. Kans. Agr. Exp. Sta. Bull. 127: 199–252, 1904.

THATCHER, R. W.: The Progressive Development of the Wheat Kernel. Jour. Amer. Soc. Agron., 5: 203–213, 1913.

WOODS, CHARLES, and MERRILL, L. H.: Entire Wheat Flour. Me. Agr. Exp. Sta. Bull. 103: 61–80, 1904.

CHAPTER XI

AVENA (Oats)

Oats are annual. The large majority of varieties are summer annuals; a very few are winter annuals.

Roots.—The root system of oats is very similar to that of wheat. The dense, fibrous growth, which in wheat occurs in about the first 2 or 3 feet of soil, is somewhat deeper in oats. The roots of oats extend to a depth of 3 or 4 feet. To quote from Ten Eyck, "Extending down from the center of the root crown of each plant in this example was observed a short rudimentary root stem which ended abruptly with a slight enlargement from which radiated a few short, fine, wire-like roots. Often the old seed coat was found clinging to the enlarged terminus. The depth at which the seed was planted determined the length of the lower root stem. The explanation of this rudimentary growth is that the seed was planted too deep, or below the point at which soil conditions were most favorable for starting the young roots; hence, the root crown formed considerably above the seed, the lower root stem remaining rudimentary and the little rootlets which started from it ceasing to grow early in the season." Weaver finds that the average "working depth" of oats roots in the short-grass plains, the mixed prairie, and true prairie is 2.7 feet, 3.4 feet and 3.4 feet respectively, and the maximum depth, 3.4 feet, 4.2 feet, and 4.4 feet respectively.

Stems.—As compared with wheat, the stems of oats are larger in diameter and softer. The number of joints in the culm varies from four to eight.

Leaf.—Oats produce abundant leaves. They are broader, as a rule, than those of wheat. The leaf sheath is closed.

The ligule is short, oval, and with distinct teeth, thereby differing from wheat, rye, and barley. The young leaves are rolled to the left. The auricles are lacking, which also distinguishes it from the other small cereals.

Inflorescence.—The spikelets of oats are arranged in a panicle. The branching on the main axis is racemose, that

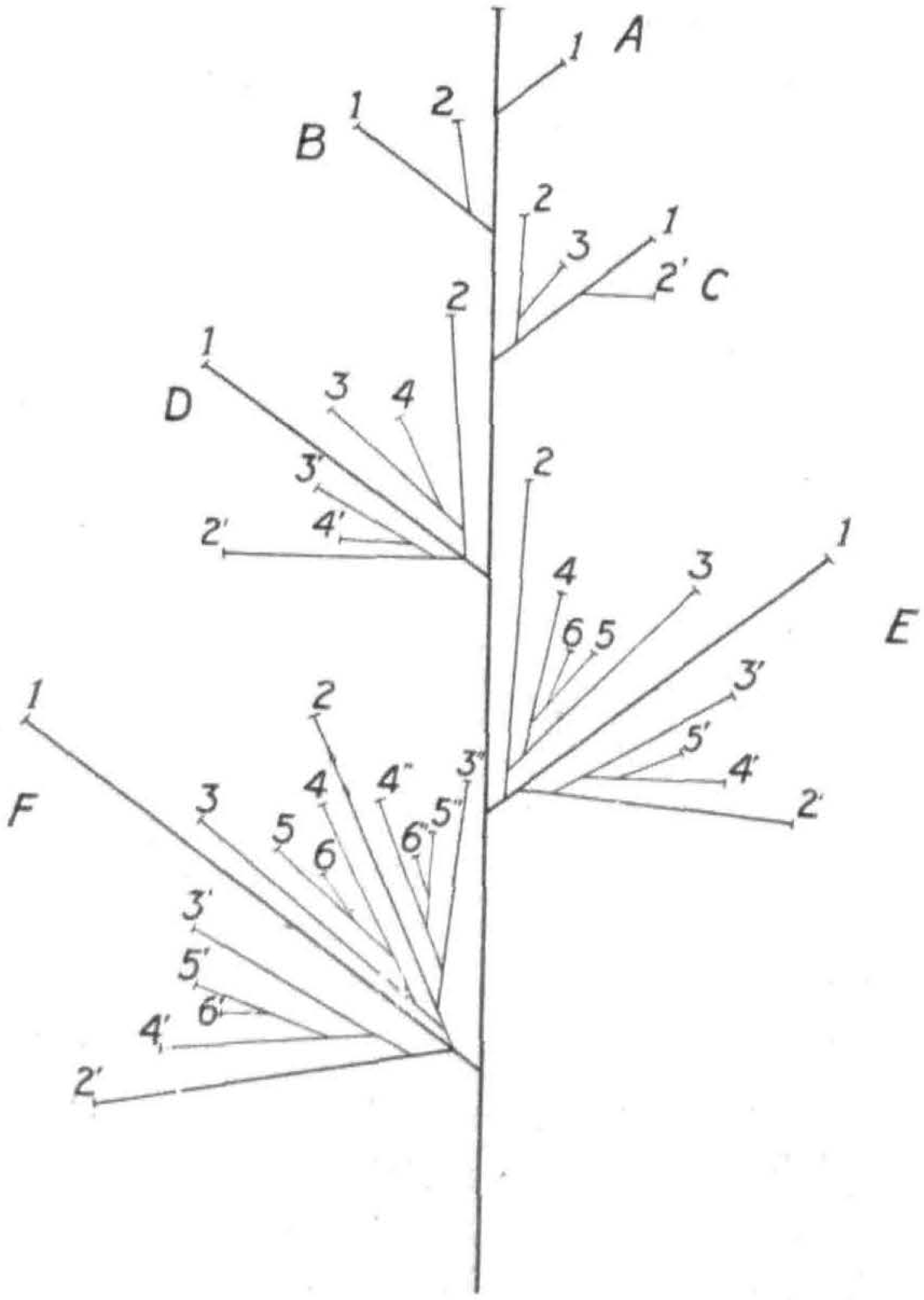


FIG. 47.—Diagram of oat inflorescence. (*After Broili.*)

of a higher order is cymose (Fig. 47). The number of whorls in a panicle ranges from four to nine, mostly five or six. Apparently, there are a number of primary branches arising at a node. However, there is only one primary

branch, the others being branches of higher order, arising at the base of the primary. The branching decreases from bottom to top.

In banner oats (*Avena orientalis*), the panicle is one-sided. In ordinary panicle or spreading oats (*Avena sativa*),

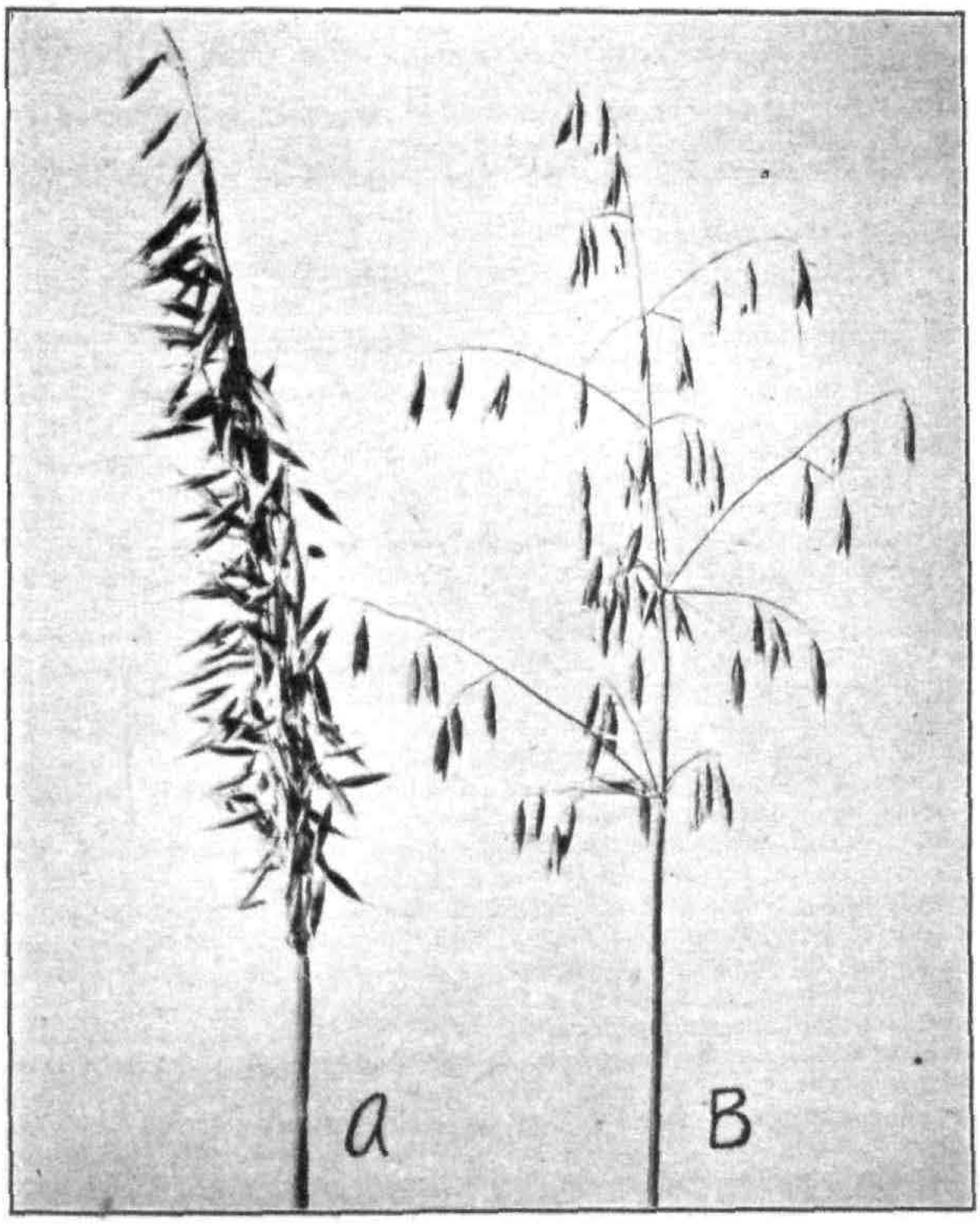


FIG. 48.—*A*, contracted, one-sided panicle of banner oats (Avena orientalis); *B*, spreading inflorescence of panicle oats (Avena sativa).

the branches spread toward all sides (Fig. 48). Four main types of panicle oats have been distinguished at the Svalof Experiment Station, as follows: (1) Panicle stiff and upright, (2) panicle pyramidal, the branches long, slender, and rising weakly, (3) panicle widely spreading, (4) panicle with branches weak and drooping.

The number of spikelets in a panicle varies, an average number being near 75. The rachis is straight or only slightly undulating. A single spikelet is borne at the end of a slender pedicel, which varies in length.

Spikelet and Flower (Fig. 49).—The number of flowers in an oat spikelet varies from two to five, rarely it is one. Three, however, is the usual number. In the so-called "*single oats*," but one flower, the basal, matures. In "*twin oats*," two flowers mature. Three kernels occasionally

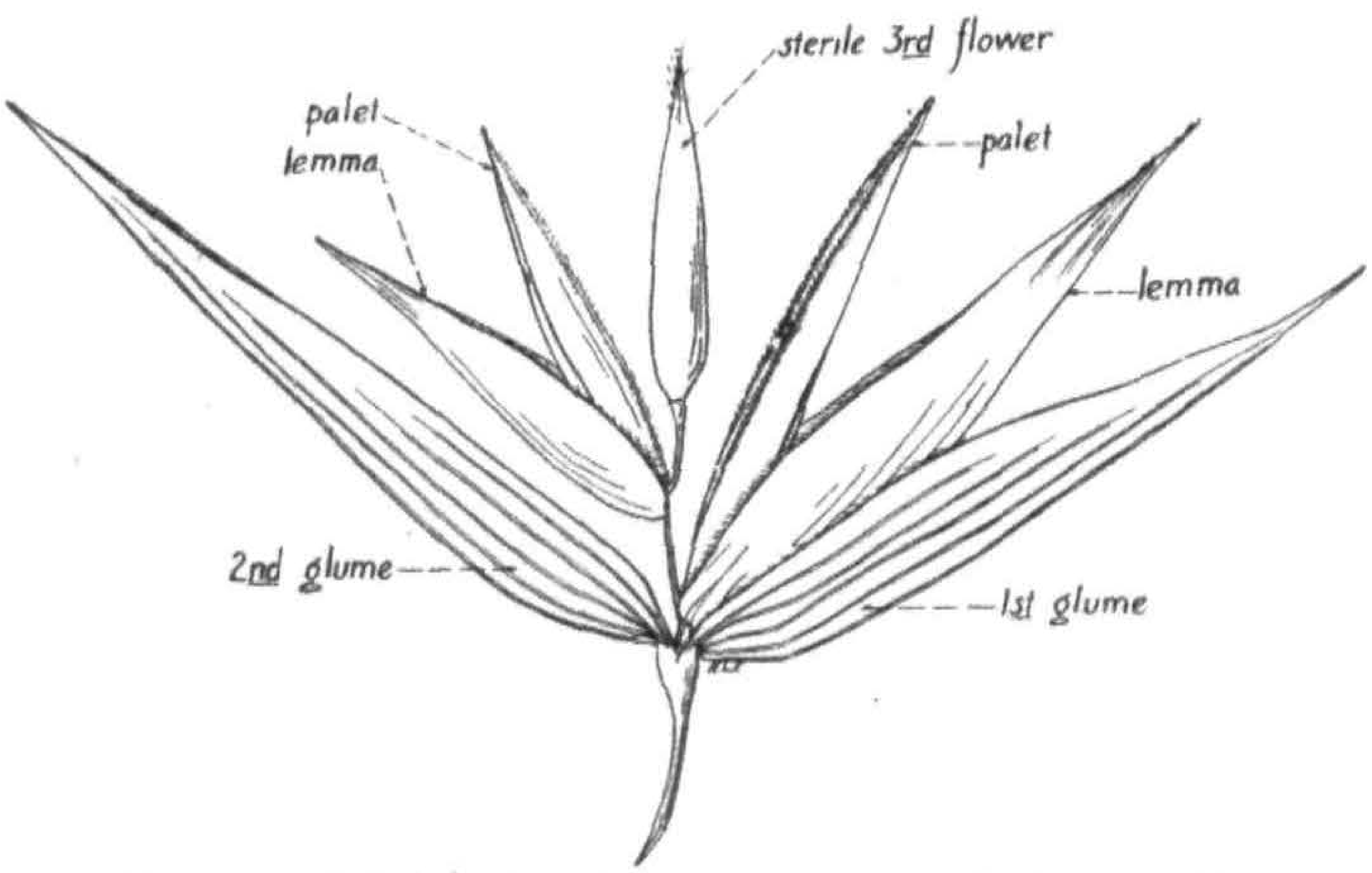


FIG. 49.—Spikelet of panicle oats (Avena sativa). × 2½.

mature. The upper flowers of the spikelet are often staminate or imperfect. If a large number of spikelets bear three kernels, there is usually a reduction in the number of spikelets in the panicle, as well as in the total weight of grain from that panicle.

The two empty glumes are unequal, and longer than the lemma. The lemma is rounded on the back, acute, and usually bears an awn which is dorsally attached. As a rule, the lower flower is the only one to bear an awn. The palet is two-toothed, and shorter than the lemma. It fits closely

about the grain. Stamens three. Style branches two, plumose. Lodicules two, very evident at flowering time.

Opening of Flower and Pollination.—The inflorescence opens at the tip first. In oats, as in other paniculate types of inflorescences, there are a number of cells in the axils of the primary branches which become turgid and bring about the opening of the inflorescence. The first flowers to open in the panicle are in the middle spikelets. The blooming of the entire panicle is completed in six to seven days. In the spikelet, the lower flower opens first, then the second and third in order. The chief blooming time of oats is from 2:00 to 4:00 p.m. Blooming may continue at slackened speed until 7:00 or 8:00 p.m. A flower usually remains open from fifty to seventy minutes. Hence cross-pollination is not excluded. Self-pollination is the rule, however, due to the fact that all three anthers seldom project from the flower. In cool or rainy weather, flowers may not open at all.

Fertilization, and Maturing of Grain.—Oats and wheat are very similar as to fertilization. The oat grain passes through the milk and waxy stages to maturity, as in wheat. After the resorption of the outer integuments, resorption of the parenchyma layer begins. There is a complete resorption of the chlorophyll layer and the inner epidermis. There seems to be a less marked fusion of pericarp and seed coats than in wheat.

The Mature Grain.—The kernel is firmly surrounded by the lemma and palet, except in "naked oats." The lemma and palet form the "hull" (Fig. 50). The quality of oats is judged largely on the basis of per cent. hull and kernel. Hull usually forms from 25 to 33 per cent. of grain weight, but may be as low as 20 per cent. or as high as 45 per cent. The percentage of hull in the upper grains of a spikelet is less than that of lower grains. It is also stated that early-ripening sorts have a greater percentage of hull than late-

ripening ones. The reports are conflicting concerning the percentage of hull in short plump grains and in long slender ones. Furthermore, there is no constant relation between weight of grain per bushel and per cent. of hull. However, if

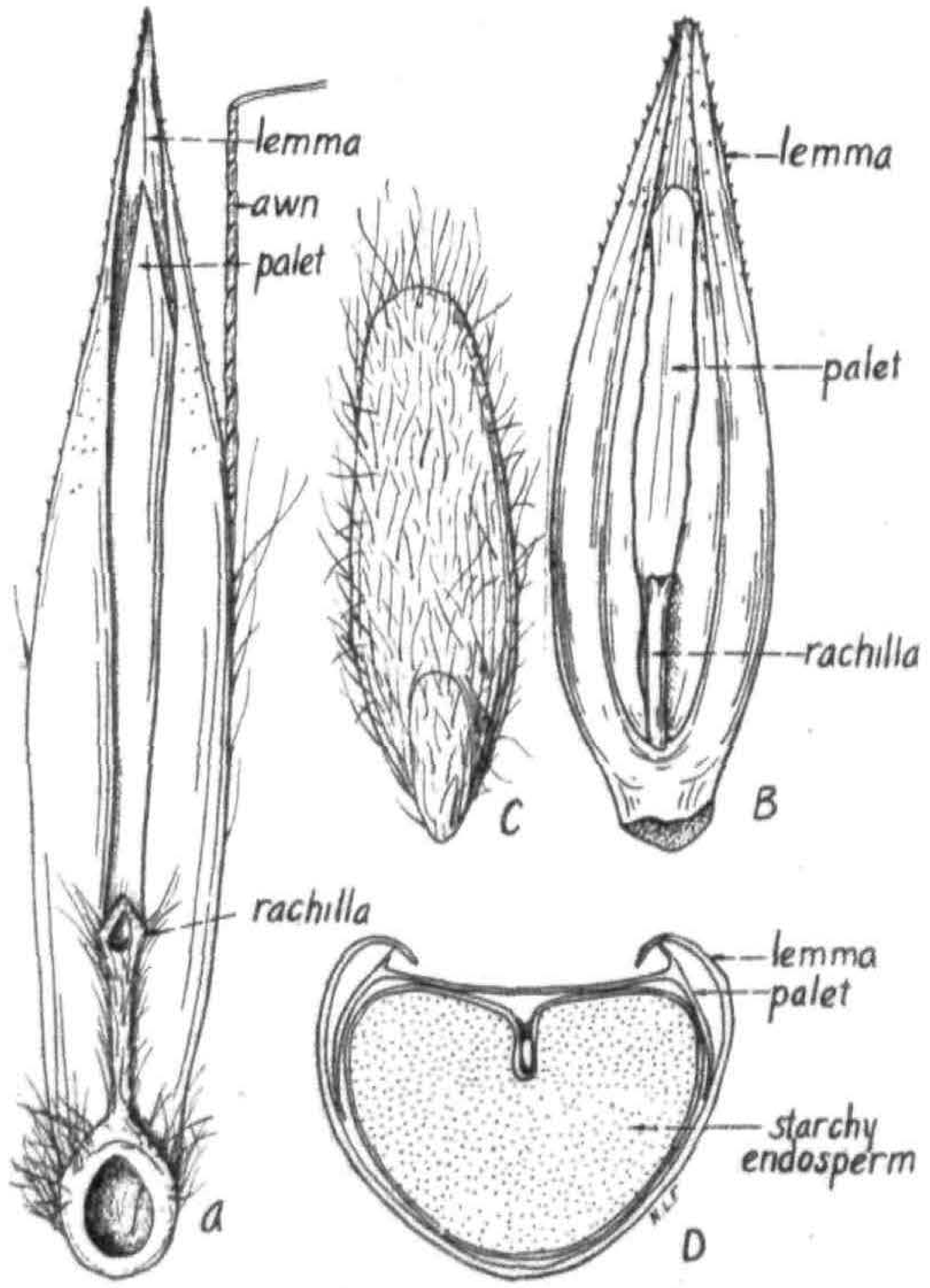


FIG. 50.—*A*, mature grain of wild oats (Avena fatua); *B*, mature grain of cultivated panicle oats (Avena sativa); *C*, grain of same with "hull" removed; *D*, cross-section of grain with the "hull." *A*, *B* and *C*, × 5; *D*, × 10.

an oat variety is well adapted to a certain region, the per cent. of hull is quite generally lower than if it is poorly adapted.

There are marked differences in the basal and upper grains of a spikelet. The basal grain is the largest and usually bears an awn; the upper ones rarely have awns. A short rachilla (Fig. 50), which bears the second grain, is at the

base of the lower kernel. This rachilla varies in length, shape and hairiness in the different oat varieties. The second grain commonly carries no rachilla, or only a fine, thread-like one at the end of which is an immature grain or the mere remnants of a third flower. The base of the outer grain is blunt, while that of the inner is pointed.

The oat kernel (Fig. 50) is elongated and has a hairy surface. As in wheat, the embryo forms a very small portion of the kernel. A cross-section of the grain shows the following coats: (1) *lemma;* (2) *palet*, of six to eight cell layers; (3) *pericarp*, a thin layer of two or three rows of cells: (4) *testa*, two layers of inner integument; (5) nucellus, one layer; (6) *aleurone layer*, two rows of cubical cells (sometimes one); (7) *starchy endosperm.*

The starchy endosperm of oats, unlike that of wheat, possesses no gluten, and hence it cannot be made into light bread. In this respect it resembles barley. The double row of aleurone cells also distinguishes the oat grain from the wheat grain. The other grain coats and the embryo are very similar.

Germination of Oats.—The cardinal temperatures (maximum, optimum and minimum) for oats are about the same as they are for wheat.

The young shoot breaks out at the germ end, grows underneath the lemma, and comes out at the brush end. This method of growth is necessitated by the persistence of the palet and lemma. The primary root, however, ruptures the hull. The coleoptile is closed. The first foliage leaf is rolled.

Classification of Oats.—The common oat varieties in the United States fall into three species: *Avena sativa, A. orientalis*, and *A. nuda*. The latter two are sometimes given as varieties of *A. sativa*.

Avena sativa (panicle oats).—The common oats belong to this species. In these, the panicles are spreading in all directions (Fig. 48). A considerable number of forms are recognized. Four main types, based upon character of panicle, were given on page 127. As to color of grain, there are white, yellow, gray (winter oats), brown and black sorts. Some are bearded and some are beardless.

Avena orientalis (banner, side, mane, or Tartarian oats).—The panicles of these species have erect branches which are close to the main axis (Fig. 48). The inflorescence is one-sided, which character has suggested the common names ascribed to it. There are beardless-white, bearded-white; beardless-yellow, beardless-brown, and bearded-brown varieties.

Avena nuda (naked or hull-less oats).—The grains of this oat fall from the hull when threshed. It may be either a spreading or side type.

Other Cultivated Oats.—In addition to the three common species of oats given above, the following species are recognized and cultivated in various parts of the Old World: *Avena strigosa* (rough oats), *A. brevis* (short oats), *A. byzantina* (Mediterranean oats) and *A. abyssinica* (Abyssinian oats).

Avena fatua ("wild oats").—The so-called "wild oat" is often found in oat fields, and the "seed" may frequently occur as an impurity in farm seed. The plant has slender stems, which are long, and hence it usually stands above the cultivated oats. It has three flowers to a spikelet, and the awns on the lemmas are strongly bent (Fig. 50). It is distinguished from the common oats by the long reddish-brown hairs at the base of the lemma and on the rachilla, and by the distinct articulation of its grains.

In cultivated sorts, there appears occasionally the so-called "false wild oats," differing in its characteristics both from

the cultivated varieties and the true wild oats. It differs from the cultivated varieties in having the long twisted and bent awns. The kernels, however, are similar to those of the cultivated varieties.

The following key to the "principal cultivated varieties of oats, together with their wild species," is taken from Etheridge.

Kernel loose within the surrounding hull; lemma and glumes alike in texture.
Kerneal firmly clasped by the hull; lemma and glumes alike in texture.
  Upper grains persistent to their rachillas.
  Upper grains easily separated from their rachillas.
    Lemma extended as teeth or awn points.
      Lemma with 4 teeth or awn points.
      Lemma with 2 teeth or awn points.
        Lemma elongate, lanceolate, with distinct awn points.
        Lemma short, abrupt, blunt, rather toothed than awn-pointed.
    Lemma without teeth or awn points.
      Basilar connections of the grains articulate.
      Basilar connections of the grains solidified.
        Panicles roughly equilateral, spreading.
        Panicles unilateral, appressed.

Origin of Oats.—It is held by a number of workers, that all the varieties belonging to *A. sativa*, *A. orientalis*, and *A. nuda* have originated from *A. fatua*. Under cultivation, *A. fatua* has lost the fragility of its articulations, its hairs and, in some instances, its awns. *A. strigosa* and *A. brevis* are derived from *A. barbata*, a species growing wild in the Mediterranean region, Persia, Mesopotamia, west to Atlantic Europe and Great Britain. *A. abyssinica* is originated from *A. wiestii*, a species indigenous to North Africa and Arabia. *A. byzantina* has come from *A. sterilis*, the so-called "animated" or "fly" oats, a wild form frequent in the Mediterranean region. Trabut has found in this region all forms of *Avena sterilis* ("sterile" oats), beginning with those that are small and useless and ending with the forms now cultivated

there. Algerian oat (*A. algeriensis*) is the common cultivated variety of the sterile oat.

All the forms of oats derived from *A. fatua* are characterized by the easy separation of the second flower from the rachilla, which persists above the lower flower. In those forms of oats derived from *A. sterilis*, on the other hand, the second flower does not separate from the lower flower without carrying away the rachilla at its base.

Environmental Relations.—Oats is adapted to a humid, moderately cool climate, such as is found in the region north of the corn belt in the United States. Cool summers favor the ripening of the grain; oats is a better crop than wheat at high latitudes and altitudes. The white and black oats are grown at higher latitudes than red and yellow sorts; the latter are raised in the Southern States, some varieties being sown as winter oats. Practically all of the oats grown in the Northern States is spring-sown.

The water requirement of oats is greater than that of any of the other common cereals. It will thrive on soils too wet for corn and in general is better adapted to heavier soils.

Leading Countries in the Production of Oats, Showing Acreage and Production, 1915

Countries	Acres	Bushels
United States	40,780,000	1,540,362,000
Russia, European	44,787,000	1,006,983,000
Germany	*	650,000,000
Canada	11,365,000	481,035,000
France	9,051,000	234,924,000
Austria-Hungary	*	234,924,000
United Kingdom	4,149,000	195,169,000
Sweden	*	70,000,000
Argentina	2,869,000	62,392,000

* No official statistics.

Uses of Oats.—Large quantities of oats are consumed annually in the form of rolled oats or oatmeal. The grain is also a much valued horse feed, and not infrequently it is fed to poultry. Oats are sometimes grown for pasture, and also cut before reaching maturity as hay. It makes an excellent nurse crop. Oat straw is used as roughage for stock, and as a bedding.

The Production of Oats.—As is the case with wheat and corn, the United States also leads all other countries in the production of oats. Russia is a close second. Iowa, Illinois and Minnesota were the leading States in 1915.

References

ATTERBERG, A.: Neues System der Hafervarietäten nebst Beschreibung der nordischen Haferformen. Landw. Vers. Stat., 39: 171–204, 1881.

BÖHMER, C.: Über die Systematik der Hafersorten sowie über einige zuchterisch wichtige Eigenschaften der Haferispe. Berlin, 1909, P. Parey. Hafer im Bilde. Fühling's Landw. Ztg., 609–616, 1911.

BROILI, J.: Beitrage zur Hafer Morphologie. Jour. Landw., 58: 205–220, 1910.

Hafer im Bilde. Arb. Deut. Landw. Gesell. Heft., 194, Berlin, 1911. P. Parey.

CANNON, W. A.: A Morphological Study of the Flower and Embryo of the Wild Oat, Avena fatua L. Proc. Cal. Acad. Sci. Ser. 3, I, No. 10: 329–364, 1900.

CRIDDLE, N.: The So-called White Wild Oats and What They Are. Ottawa Nat., 23: 127, 1909.

Wild Oats and False Wild Oats; Their Nature and Distinctive Characters. Canada Dept. Agr. Bull. 7: 1–11, 1912.

DENAIFFE AND SIRODOT: L'avoine, etc. Paris, 1902, 210 figures, pp. 848.

ETHERIDGE, W. C.: A Classification of the Varieties of Cultivated Oats. Cornell Agr. Exp. Sta. Mem. 10: 85–172, 1916.

FRUWITH, C.: Die Haferrispe bei der Beurteilung der Sorten und in der Züchtung. Fühling's Landw. Ztg., S. 289, 1907.

HASELHOFF, E.: Vergleichende Untersuchungen deutscher und amerikanischer Haferkorner. Landw. Vers. Stat., 65: 339–349, 1907.

HAUSSKNECHT, E.: Über die Abstammung des Saathafers. Mitt. Thüring. Bot. Ver. N. F. Heft, 2: 45–49, 1892.

RAUM, H.: Zur Systematisierung der Hafersorten. Fühling's Landw. Ztg., 58: 496–501, 1909.

RIMPAU, W.: Die genetische Entwicklung der verschiedenen Formen unserer Saatgerste. Landw. Jahrb., 21: 699–702, 1892.

SCHULZ, A.: Die Geschichte des Saathafers I und II. Jahrsber. Westfal. Prov. Vers. Wiss. W. Kunst. Munster., 41: 204–217, 1913.

Abstammung und Heimat des Saathafers. Mitt. Thuring. Bot. Ver. N. F. Weimar., 31: 6–11, 1914.

TANNERT, PAUL: Entwickelung und Bau von Blüte und Frucht von Avena sativa L. Inaug. Diss. Zurich, 1905.

THELLUNG, A.: Über die Abstammung, den systematischen Wert und die Kulturgeschichte der Saathafer-Arten (Avena sativæ Coss.) Vrtljschr. Naturf. Gesell. Zurich, 56: 293–350, 1911.

TRABUT, L.: Origin of Cultivated Oats. (Translation) Jour. Hered., 5: 74–85, 1915.

Contribution a l'etude de l'origine des avoines cultivees. Compt. Rend., 149: 227–229, 1909.

VIERHAPPER, F.: Zur Systematik der Gattung Avena. Verhandl. K. K. Zool. Bot. Gesell. Wein., 56: 369–370, 1906.

ZADE: Die Zwischenformen von Flughafer (Avena fatua) und Kulturhafer (Avena sativa). Fühling's Landw. Ztg., 369–384, 1912.

CHAPTER XII

HORDEUM (Barley)

Barley is grown as either a summer or winter annual. It has been observed that two-rowed barley (*H. distichon*), has a distinct tendency toward the perennial habit like rye. Plants that were mowed down in July sent up new sprouts which developed inflorescences the following September, and after removing these, a third set of sprouts was sent up. It has been suggested that our cultivated barleys are derived from a perennial form and that in the course of time this habit has been lost.

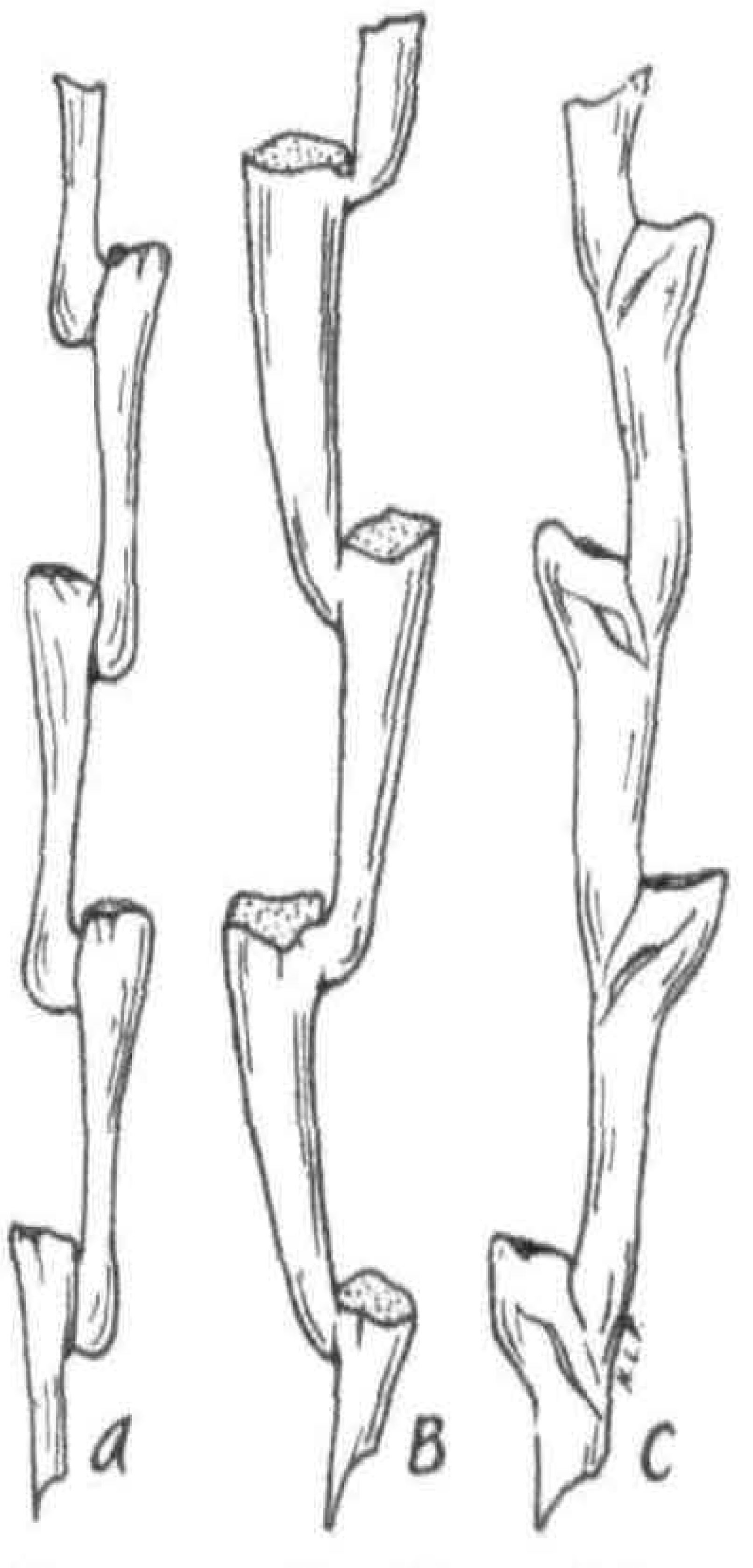


FIG. 51.—Rachises of three common cereals. *A*, barley; *B*, wheat; *C*, rye. × 5.

Roots, Stems, Leaves.—The root system of barley resembles that of oats. The culm has from five to seven joints, sometimes eight, the length of which increases from below upward. Barley does not tiller as abundantly as oats and winter wheat. The leaves resemble those of wheat. The auricles, however, are usually very much pronounced, and may be used as a basis of distinction between the straws (Fig. 26).

Inflorescence.—The inflorescence is a cylindrical spike, the shape of which varies slightly in the different barley types. The rachis is strongly compressed. Opposite each

point on the rachis where the spikelets stand, there is a sharply defined horizontal cushion (Fig. 51). This distinguishes the barley rachis from that of wheat and rye. Furthermore, the single joints of the barley rachis are straight, while in wheat and rye they are bent.

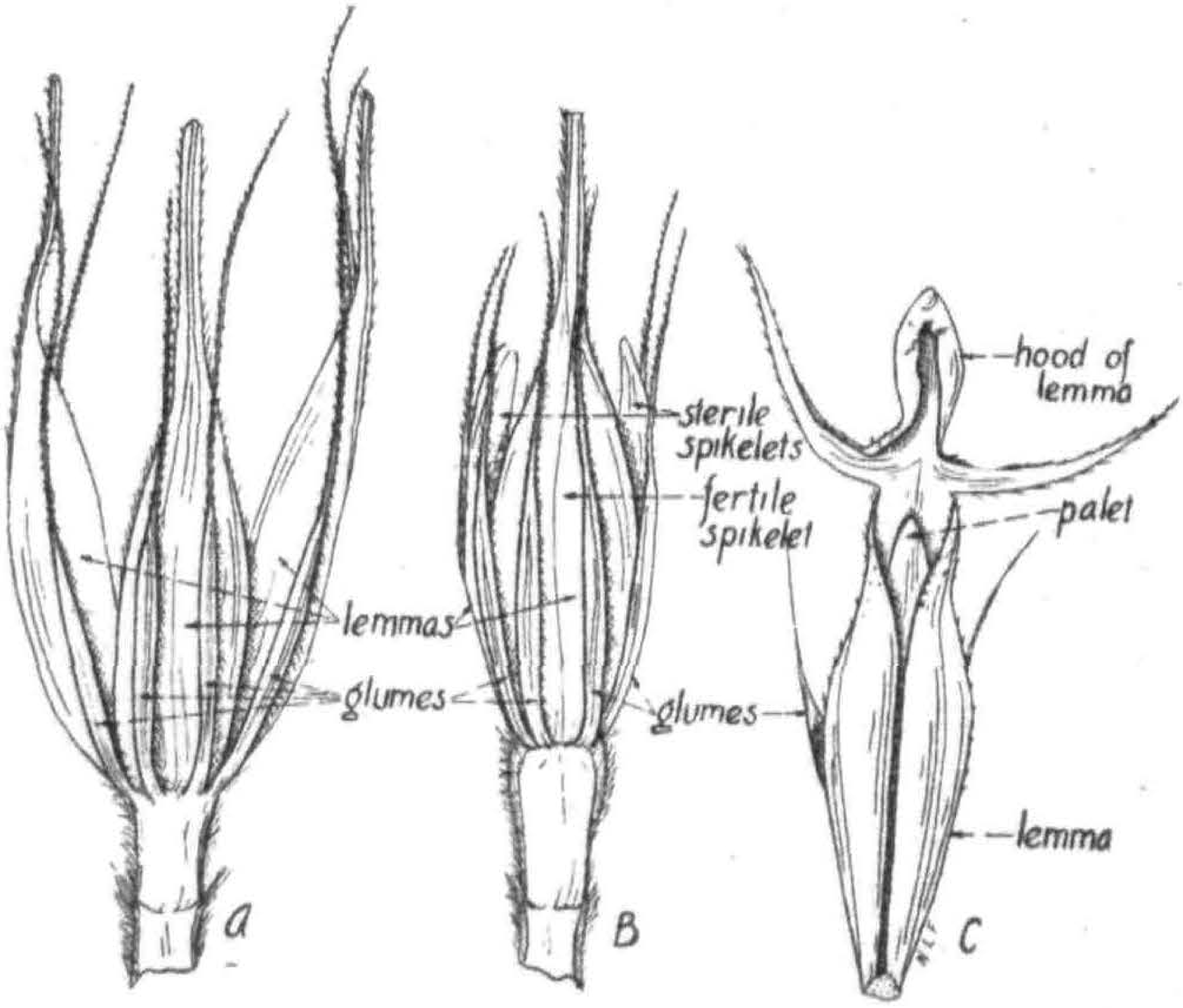


FIG. 52.—*A*, triplet of spikelets of six-rowed barley (Hordeum vulgare hexastichon); note that there are three fertile spikelets at the rachis joint; *B*, triplet of spikelets of two-rowed barley (H. distichon); the two lateral spikelets are sterile; *C*, single spikelet of hooded barley (H. vulgare trifurcatum).

At each joint of the rachis, there are three spikelets, each one-flowered (Figs. 52 and 53). The lateral spikelets of each triplet are sometimes imperfect, as in two-rowed barley. Each spikelet is on a short branch or rachilla, which is projected beyond the flower and appears as a bristle (Fig. 53) lying within the groove of the grain. As in wheat, there is no apical spikelet in barley. The groups of spikelets are arranged alternately on the rachis.

Spikelet and Flower.—Each spikelet is one-flowered. The glumes are narrow and awn-like, forming an apparent involucre about the spikelets. The lemma is broad, rounded on the back, five-nerved at the apex and bears a long awn with strongly barbed edges. In threshing barley care is taken not

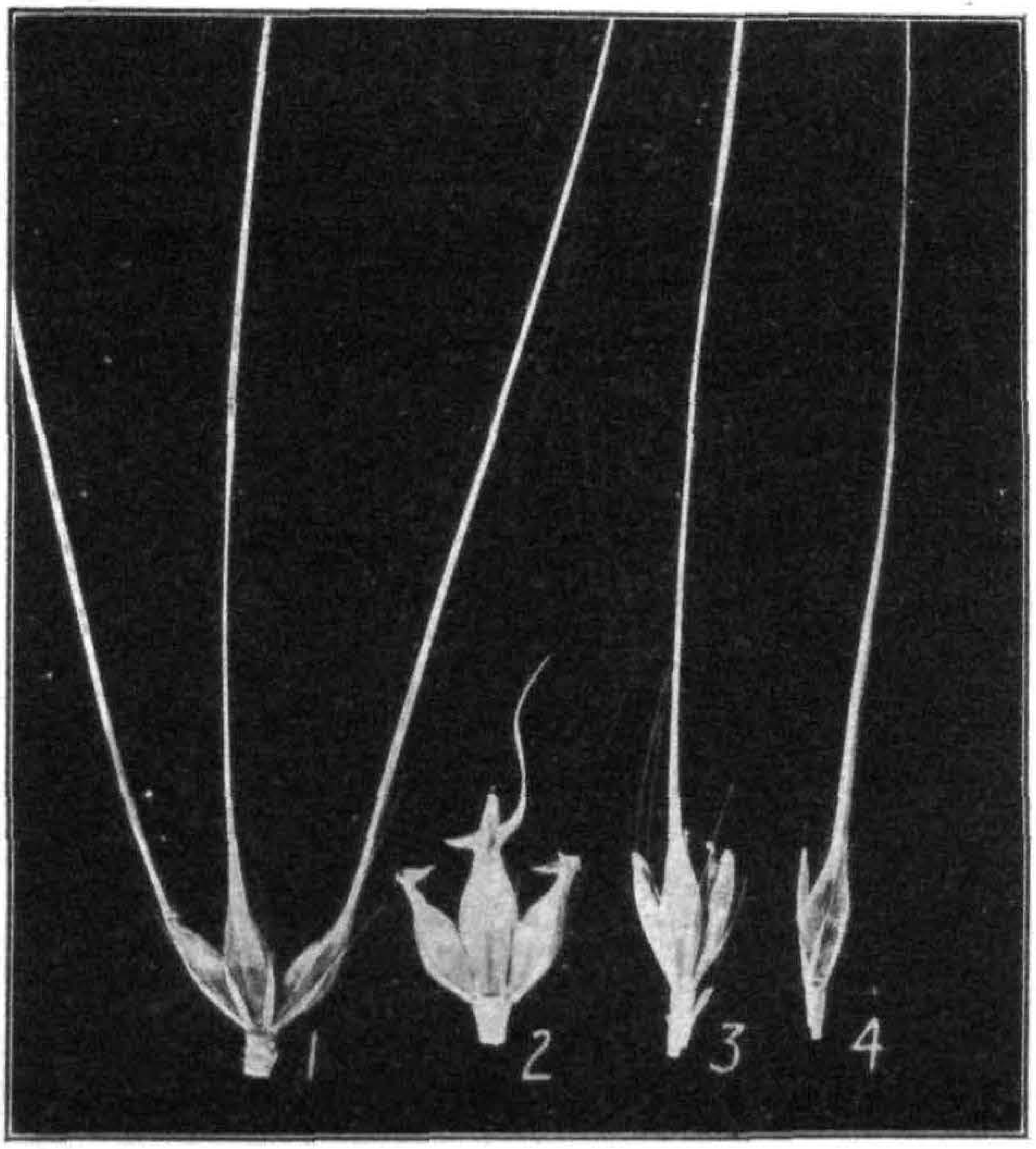


FIG. 53.—1, triplet of spikelets of six-rowed barley (Hordeum vulgare hexastichon); 2, of hooded barley (H. vulgare trifurcatum); 3, of medium barley (H. vulgare intermedium); 4, of two-rowed barley (H. distichon). Nat. size.

to break the awn so close that the end of the kernel is exposed, for by so doing, a point of attack for molds is furnished.

The palet is about the same length as the lemma, and bears two ridges. The styles are short, and the two lodicules are conspicuous and vary in the different types.

Opening of Flower and Pollination.—The blooming of a spike begins slightly above the middle and proceeds from this point upward and downward. The middle flowers of a triplet come to maturity earlier than the laterals. The duration of blooming varies. Three to four days is a good average for a single spike, and seven to nine days for all spikes of a plant. The glumes of a flower remain open from twenty to thirty minutes. This period depends upon weather conditions.

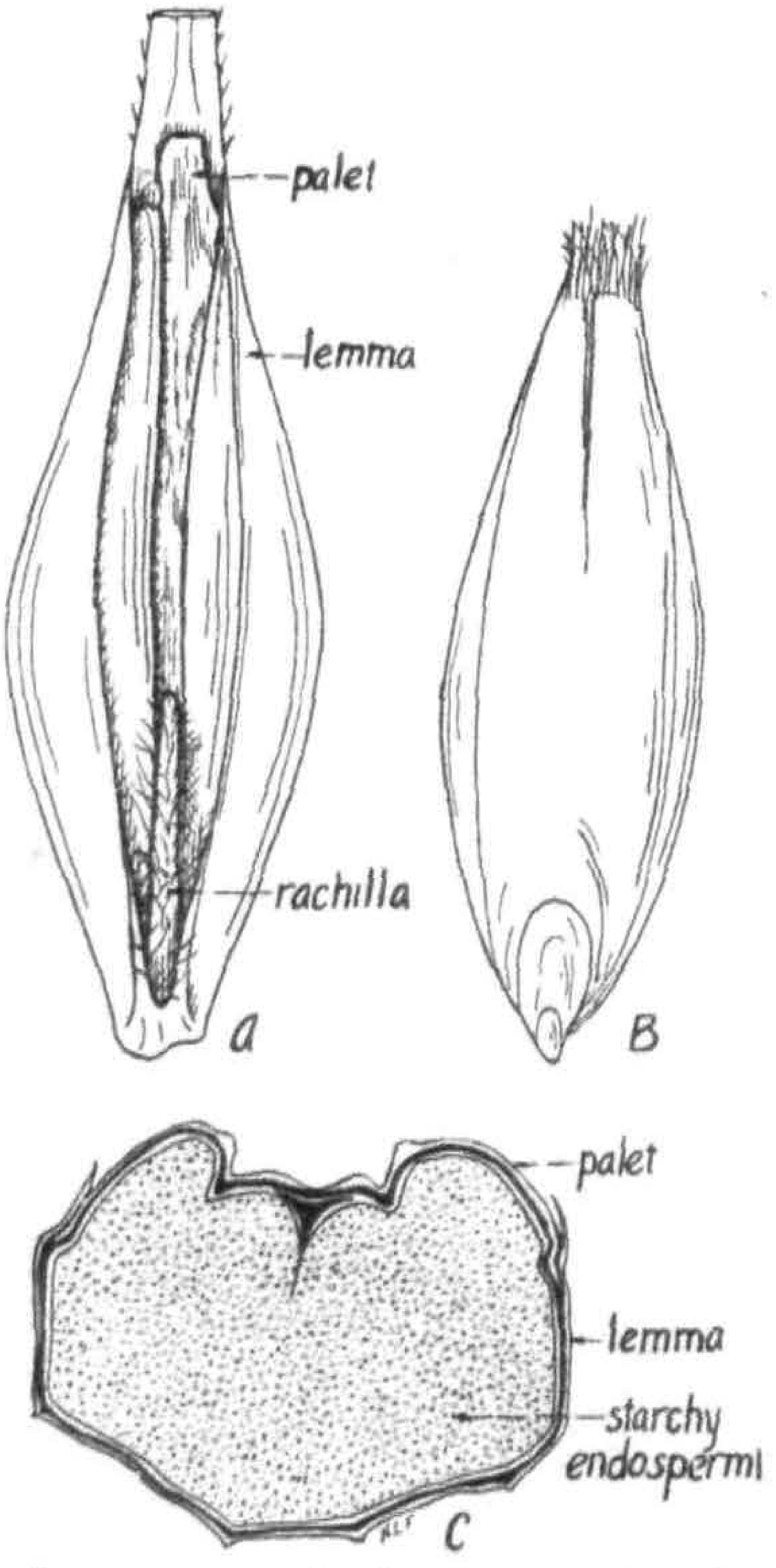


FIG. 54.—*A*, barley grain with the "hull;" *B*, with "hull" removed; *C*, grain in cross-section.

In two-rowed nodding barley, the lateral flowers bloom with open glumes, while the middle ones seldom open. Four-rowed barley almost always blooms with open flowers, both middle and side. In two-rowed erect barley, six-rowed barley and peacock barley, the flowers bloom with closed glumes. It is claimed that, in such cases, the lodicules are too weak to force the glumes apart. In four-rowed barley, in which open flowers are the rule, lodicules are well developed. It would seem, then, that in four-rowed barley and two-rowed nodding barley, there is a possibility of cross-pollination, while in six-rowed, peacock, and two-rowed erect barleys this possibility is excluded. However, very few positive cases of natural

hybridization of barleys have been observed. The reason for this probably is that the styles are short and do not protrude beyond the glumes. Rimpau examined a large number of sorts, and in all, found but eight sure cases of crossing, and these were in four-rowed barleys. Self-pollination is the rule, which means that under field conditions there is little danger that a pure strain will become impure through the introduction of characters brought in by the pollen grains of undesirable strains.

Blooming in barley begins between 5:30 and 6:00 a.m., increasing in intensity up to 8:00 a.m. Very little blooming occurs in the middle of the day. There is a slight amount between 3 and 5 o'clock in the afternoon, but by 8 in the evening all blooming has ceased.

As in all cereals, blooming is dependent upon the weather. Barleys that normally bloom with open glumes on a day with high temperature and dry atmosphere, may bloom with closed or only slightly open glumes on a cool, moist day.

Fertilization and Maturing of Grain.—The immature grain has much the same structure as that of wheat. In barley, however, the chlorophyll-bearing layer consists of two rows of cells. As in wheat, there is an early resorption of the two layers of the outer integument, and of pericarp and nucellar cells. The barley grain passes through the milk-ripe, yellow-ripe, full-ripe, and dead-ripe stages.

Mature Grain of Barley.—In hulled barleys, the palet and lemma are firmly attached to the kernel (Fig. 54). In the so-called "naked" or hull-less barley, these scales come loose from the kernel, as in common wheat. The kernel of naked barley resembles that of wheat. It is, however, pointed at both ends (Fig. 54). The kernels are broadest at the middle, in two-rowed barleys, while in the four-rowed types the kernels from the outer rows of the head are slightly twisted and those from the middle rows are broadest near the tip.

In the hulled barleys, a rachilla ("basal bristle") persists at the base of the grain on the side adjacent to the palet (Fig. 54). The character of this bristle is of some systematic importance.

The hull may form from 10 to 25 per cent. of the grain, being greater in six-rowed types than in two-rowed types. Variation in percentage of glumes may depend upon season, soil, grain shape, and perhaps fertilizers. Furthermore, Haberlandt has shown that barleys of northern regions have a smaller percentage of hull than those of southern localities.

In a cross-section of the mature grain of hulled barley, the following coats are seen:

1. *Lemma* and *palet*, five to seven rows of cells.

2. *Pericarp*, consisting of several rows of parenchyma cells and two rows of chlorophyll-bearing cells.

3. *Testa*, two layers of inner integument.

4. *Nucellus*, one row of cells.

5. *Aleurone layer*, usually of three (two to four) rows of thick-walled cells.

6. *Starchy endosperm*.

As in rye and wheat, the fruit and seed coats are more weakly developed at the embryo end than in other parts of the grain.

The embryo of barley is very similar to that of wheat. It occupies but a small part of the grain. Five to eight secondary rootlets occur. The epiblast is absent in the genus *Hordeum*. The endosperm varies from mealy to glassy or translucent. Mealiness is the result of a high percentage of starch, while translucency indicates a high percentage of protein. The relative amounts of starch and protein in the different types vary. The two-rowed barleys are used almost exclusively in brewing.

There is no gluten in barley grains, and for this reason light bread cannot be made from the flour.

Color of Grain.—Harlan has made a study of the color of barley grains. He says: "There are two coloring materials in barley: One, anthocyanin, is red in its acid and blue in its alkaline condition; the other, a melanin-like compound, is black. The pigments may occur in the hulls, the pericarp, the aleurone layer, and occasionally in the starch endosperm. The resulting colors of the grain are quite complicated. White denotes the absence of all pigment; a heavy deposit of the melanin-like compound in the hulls results in black; a light deposit, brown. Anthocyanin in the hulls results in a light violet-red. In naked forms the melanin-like compound in the pericarp results in a black kernel; anthocyanin produces a violet one. The acid condition of anthocyanin in the pericarp superimposed upon the alkaline condition in the aleurone layer gives the effect of a purple color, while a blue aleurone beneath a colorless pericarp is blue-gray. White hulls over a blue aleurone cause the grain to appear bluish or bluish gray. Black hulls over a blue aleurone give, of course, a black appearance. The anthocyanin is always violet in the hulls and in the pericarp, showing that these tissues are in an acid condition, and always blue in the aleurone layer, showing an alkaline condition. The occurrence of anthocyanin in the pericarp of hull-less barleys is more significant than its production in the aleurone layer."

Germination of Barley.—In brewing, much emphasis is placed upon the "germinating energy" of the grain. By this is meant its ability to germinate within a specified time. A high germinating energy is 96 per cent. in seventy-two hours when kept at 64.4° to 68°F.

Much importance is attached to the secretion of enzymes and the conversion of endosperm in the germinating of barley grain. A barley of high diastatic power is preferred; by this is meant the ability to produce an abundance of the starch-dissolving enzyme—diastase. Small grains, with a high

called "hooded barley." There are both naked and hulled barleys. *Hordeum vulgare coerulescens* is blue barley, *H. vulgare nigrum*, black barley, and *H. vulgare coeleste*, the hull-less Jerusalem barley.

Hordeum intermedium (medium or hybrid barley).—Under this name are included those barleys that are transition forms between the two- and many-rowed types (Fig. 55). In these intermediate forms, only the two middle rows are normally formed, the four lateral ones being beardless and smaller. It is quite probable that the *intermedium* forms are segregates of the hybrids of certain two-rowed and many-rowed forms.

Hordeum distichon (two-rowed barley).—In this, the spikes bear two longitudinal rows of grains. As in six-rowed barley, the spikelets occur in groups of three on opposite sides of the rachis, but in the case of two-rowed barley, the lateral spikelets of each triplet do not mature, only the middle one of each maturing its grain (Figs. 52 and 55). However, the glumes of the lateral spikelets develop normally. The anthers of side spikelets may be either dwarfed or well developed. The kernels of two-rowed barleys are symmetrical and broadest in the middle. The hull is thin. There is a low percentage of protein and a mealy endosperm.

There are a number of types of two-rowed barleys, two of the most important being *Hordeum distichon palmella*, and *Hordeum distichon nudum*. The former includes, among others, the three subvarieties, *zeocriton*, *erectum* and *nutans*.

Hordeum distichon zeocriton (peacock or fan barley) (Fig. 56).—The spikes are very dense and short, about 6 centimeters long, broad at the base and narrow at the tip, and with widely spreading beards.

Hordeum distichon erectum (erect-eared barley).—In this the heads are erect and broad. On the dorsal side of the grain at the base, there is a characteristic crown furrow,

so that in longitudinal section a rounded hump shows (Fig. 57). Rachis joints are from 2.1 to 2.7 millimeters long. The rachilla is hairy and broadened.

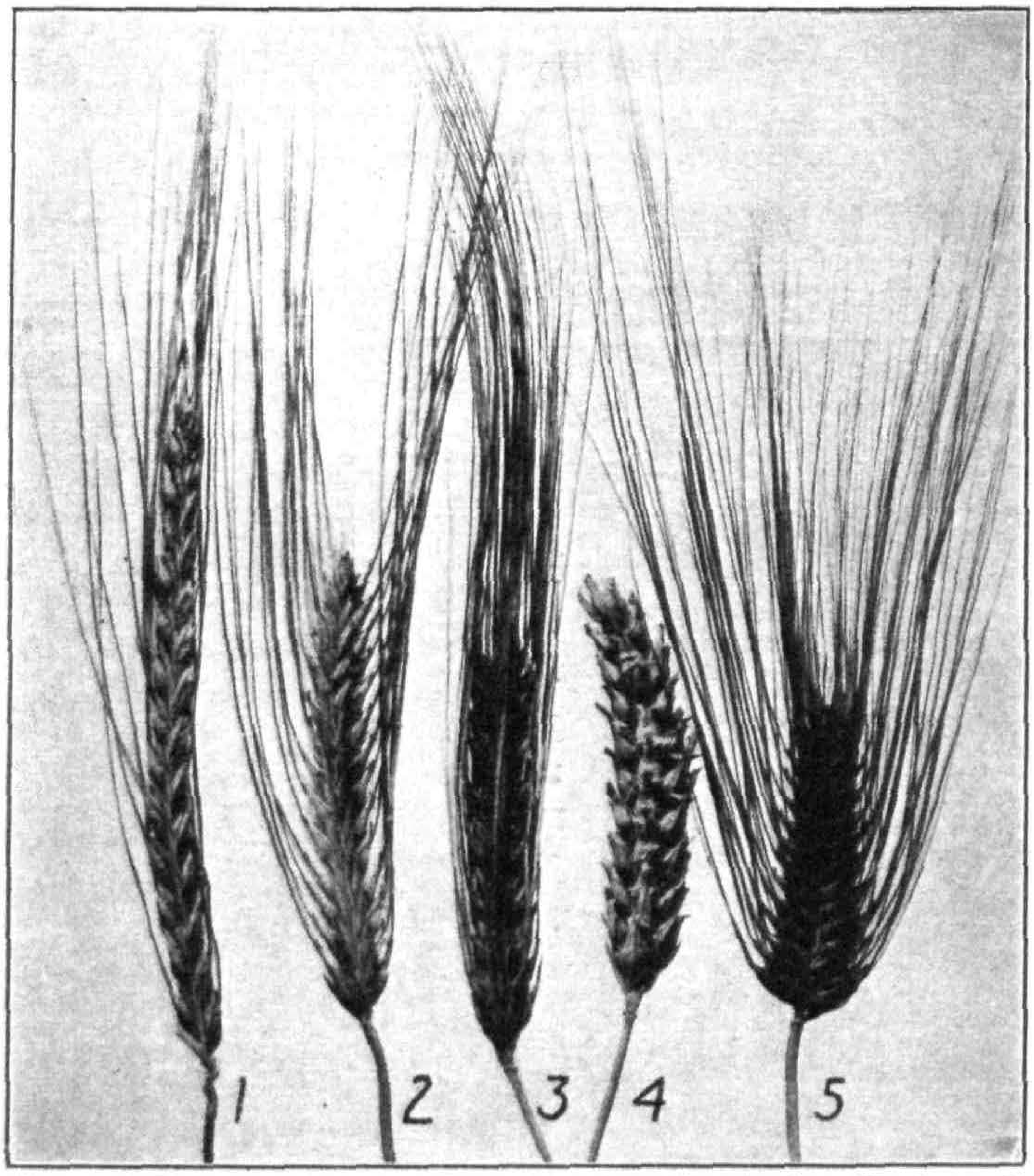


FIG. 56.—Spikes of barleys. 1, two-rowed nodding barley (Hordeum distichon nutans); 2, medium barley (H. intermedium); 3, four-rowed barley (H. vulgare pallidum); 4, hooded barley (H. vulgare trifurcatum); 5, six-rowed barley (H. vulgare nigrum).

Hordeum distichon nutans (bent or nodding barley).—In this the heads hang down when ripe. On the dorsal side of the grain at the base, there is a slight horseshoe-shaped

depression. In lengthwise section, the base of the kernel slopes off (Fig. 57). Rachis joints are 2.8 to 3.5 millimeters long. The rachilla is broom-form or very hairy. The noted malt barley, Chevalier, belongs to this type.

Hordeum deficiens.—In this barley the lateral flowers are rudimentary. There are both "hulled" and "naked"

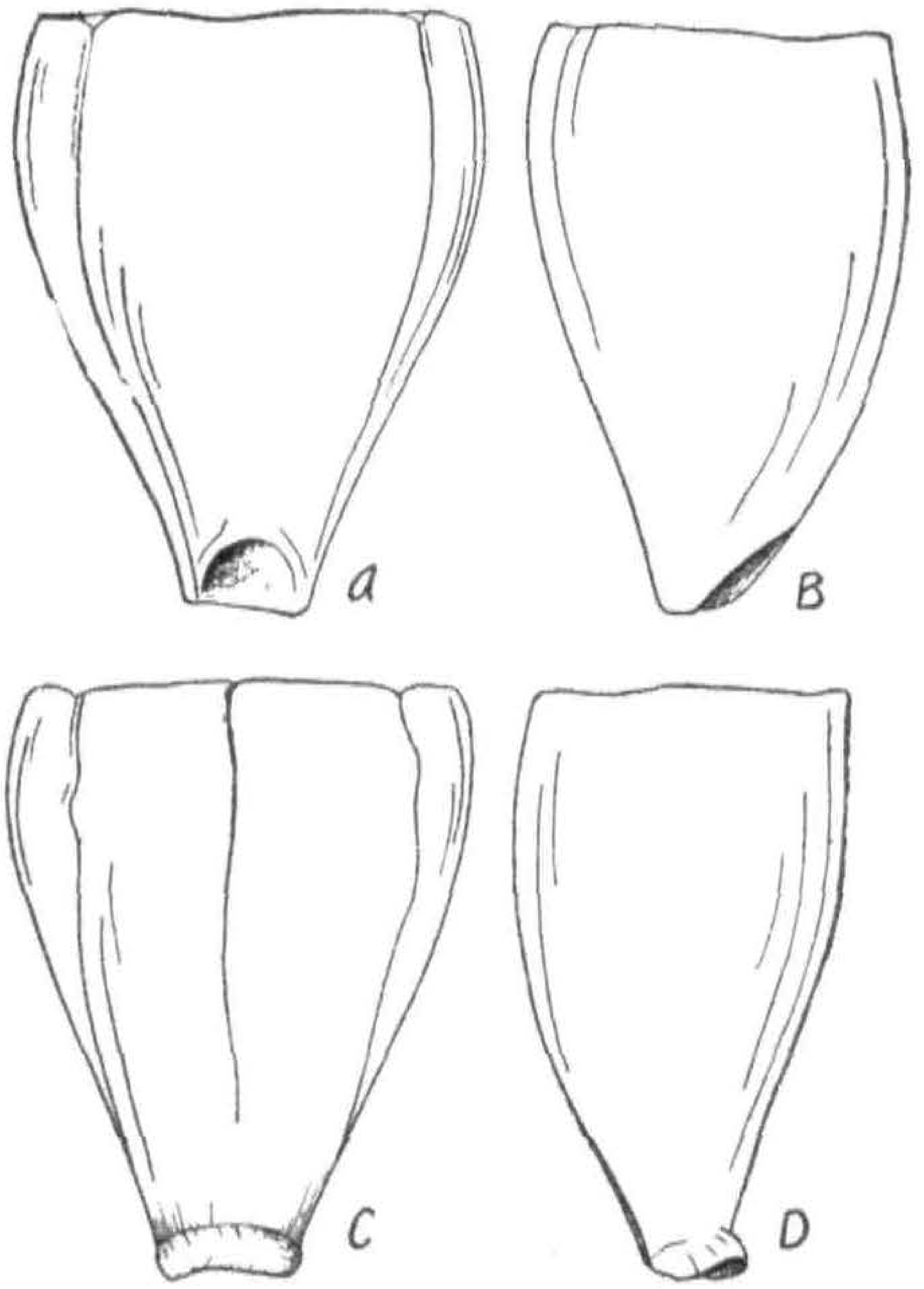


FIG. 57.—Bases of the grains of two-rowed barleys. *A*, *B*, nodding barley (Hordeum distichon nutans); *C*, *D*, erect-eared barley (H. distichon erectum). (*After Newman.*)

varieties of this species, and also those with awned or with awnless and with hooded lemmas.

Origin of Cultivated Barleys.—There are two principal opinions regarding the origin of cultivated barley, that of Koernicke and that of Rimpau. Koernicke considers *Hordeum spontaneum* to be the prototype of all our cultural forms. This wild barley is nearest related to the *nutans*

tase, which chemically invert the starch into maltose, malto-dextrin and dextrin, and change the insoluble albuminoids to a soluble form.

Boiling the Wort.—The product of the mashing machine is called "wort." During the boiling process, hops are added. Boiling serves not only to extract desirable products from the hops, but to render harmless certain undesirable constituents. After boiling, the wort is strained into coolers.

Fermentation.—Yeast is now added to the wort. This introduction of yeast is called "pitching." Through the activity of yeast, the sugar in the wort is changed to alcohol and carbon dioxide. The wort has been changed to beer. It is removed from the fermenting vat, stored for a period to allow certain products to settle, and also to permit of after-fermentation, and then clarified, filtered, and packed for the market.

Production of Barley.—The four leading countries, in 1915, in the production of barley were: Russia, United States, Germany, and Austria-Hungary, producing respectively 475,109,000; 277,009,000; 150,000,000; and 136,186,000 bushels.

References

ATTERBERG, A.: Die Erkennung der Haupt-varietäten der Gerste in den Nordeuropäischen Saat- und Malzgerstan. Landw. Versuchstat., 36: 23–27, 1889.

Die Varietäten und Formen der Gerste. Jour. Landw., 47: 1–44, 1899.

BRENCHLEY, WINIFRED E.: Development of the Grain of Barley. Ann. Bot., 26: 903–928, 1912.

BROILI, J.: Über die Unterscheidung der zweizeiligen Gerste-Hordeum distichum-am Korne. Inaug. Diss. Univ. Jena, 1906.

Das Gernstenkorn im Bilde. Stuttgart, 1908.

BROWN, H. T., and ESCOMBE, F.: On the Depletion of the Endosperm of Hordeum Vulgare during Germination. Proc. Roy. Soc. (London), 63: 3–25, 1898.

FRUWIRTH, C.: Das Blühen der Gerste. Fühling's Landw. Ztg., S. 544, 1906.

HARLAN, HARRY V.: Some Distinctions in Our Cultivated Barleys, with Reference to Their Use in Plant Breeding. U. S. Dept. Agr. Bull. 137, 1–38, 1914.

The Identification of Varieties of Barley. U. S. Dept. Agr. Bull. 622: 1–32, 1918.

HENNING, E.: Beobachtungen über das Blühen der Gerste (Schwedisch). Bot. Notiser., 1905.

HUMMEL, A.: Die botanischen Unterscheidungsmerkmale bei zweizeiliger Gerste. Illus. Landw. Ztg., 830–839, 1909.

JOHANNSEN, W.: Entwickelung und Konstitution des Endosperms der Gerste. Ztschr. Gesam. Brauw., 1905.

KRAUS, C.: Die Gliederung des Gersten- und Haferhalmes und deren Beziehungen zu den Fruchtständen. Beiheft I der Naturwis. Ztsch. für Land- und Forstwirthschaft. München, 1905.

MANN, ALBERT, and HARLAN, H. V.: Morphology of the Barley Grain with Reference to its Enzyme-secreting Areas. U. S. Dept. Agr. Bull., 183: 1–32, 1915.

QUANTE, HUGO: Die Gerste, ihre botanischen und brautechnischen Eigenschaften und ihre Anbau. Berlin, 1913.

RIMPAU, W.: Die genetische Entwicklung der verschiedenen Formen unserer Saatgerste. Landw. Jahrb., 21: 699–702, 1892.

SCHULZ, A.: Die Geschichte der Saatgerste. Ztschr. Naturw., 83: 197–233, 1912.

Die Abstammung der Saatgerste, Hordeum sativum I-II. Mott. Naturf. Gesell. Halle, 1: 18–27, 1912.

TSCHERMAK, E.: Die Blüh- und Fruchtbarkeitsverhältnisse bei Roggen und Gerste und das Auftreten von Mutterkorn. Fühling's Landw. Ztg., S. 194, 1906.

VOSS, A.: Versuch einer neuen Systematik der Saatgerste. Jour. Landw., 33: 271-282, 1885.

WIGGANS, ROY GLEN: A Classification of the Cultivated Varieties of Barley. Cornell Agr. Exp. Sta. Mem. 46: 369–456, 1921.

ZOBL, A., and MIKOSCH, C.: Die Funktion der Grannen der Gerstenahre Zitzber. Akad. Wiss. (Vienna) Math. Naturw. Kl. 101: Abt. 1, 1033–1060, 1892.

CHAPTER XIII

SECALE CEREALE (Rye)

Rye is an annual. It is reported, however, that rye stubble in a field may sprout after long standing, or that close pasturing for a season may cause it to live through a second winter. This is no doubt a reversion to the perennial habit displayed by the species from which our cultivated rye came.

Roots.—Rye throws out a whorl of four primary roots, thus differing from the other cereals. The root system branches profusely in the first foot of soil and extends to a depth of 4 or 6 feet, depending upon the type of soil. It has been shown that "branching is usually better developed in rye than in wheat or oats, when growing in the same soil type and under the same conditions of moisture. This is one reason why rye is adapted to drier climates than wheat and will thrive on poorer and sandier soils than any of the other cereals." (Weaver.)

Stems, Leaves.—As compared with wheat, oats and barley, the stems of rye are tougher, slenderer, and longer. There are commonly five to six, rarely four to seven stem joints. The leaves are similar to those of wheat. The ligule is short and somewhat rounded. The auricles are white, narrow and wither early; sometimes they are absent altogether.

Inflorescence.—This is a spike. It is usually somewhat longer than the wheat spike, and is rather uniformly four-rowed. There are from 20 to 30 rachis joints. There is a single spikelet at each joint. All the spikelets, from base to tip, are fertile. The spikes have no terminal spikelet.

Spikelet.—Each spikelet (Fig. 58) consists of three flowers. The two lateral flowers mature grains, the middle one aborts. The glumes are very narrow; the lemma is broad, keeled, and bears a long, terminal awn; the keel is strongly barbed; the palet is thin, blunt and two-keeled. The lodicules are small, membranous, and ciliate on the upper margins. There are three stamens, and a single pistil with two feathery stigmas.

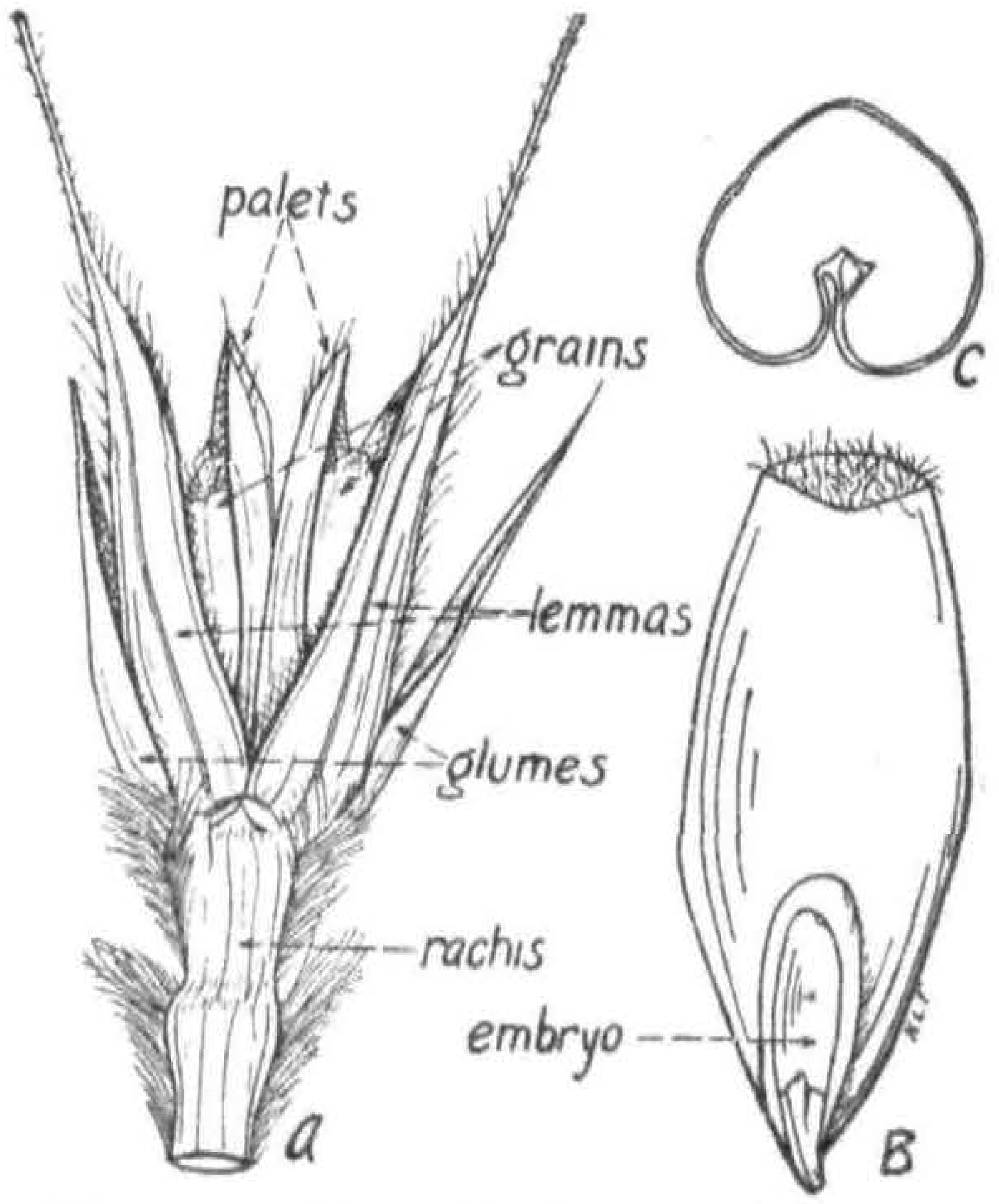


FIG. 58.—Rye (Secale cereale). *A*, a single spikelet at a joint on the rachis; *B*, grain, external view; *C*, grain in cross-section. *A*, × 2½; *B* and *C*, × 5.

Opening of the Flower, Pollination and Fertilization.—Rye is the only common cereal, besides corn, that is regularly cross-fertilized. These two cereals cannot be self-fertilized without a reduction in vigor and productivity. Apparently, no ill effects result from self-fertilization of barley, wheat and oats. According to some observers, the pollen of rye is impotent on the stigma of the same flower. It is stated that the flower is completely closed within twenty-five to thirty minutes after it begins to open, providing the stigmas receive pollen. In case the stigmas are not dusted, the flowers remain open much longer. Blooming begins between 5:00 and 6:00 a.m. and continues until 9:00 or 11:00 a.m. Then blooming decreases throughout the afternoon, becoming more rapid again in the evening. The first flowers to open are slightly above the middle of the spike. It has been observed that the flowers of rye like those of other cereals can be induced to open by rubbing with the hand, or by other mechanical stimulation.

Maturing of Grain, and Mature Grain.—The anatomical structure of the ovary at blooming time is similar to that of wheat, as are also the changes which take place in the grain during its ripening.

The mature grain (Fig. 58) is free from the lemma and palet. It is long, narrow, and usually darker in color than wheat. The cross-section of the mature grain shows layers similar to those in wheat, although different from it in details.

Rye protein usually forms about 6 to 12 per cent. of the grain. Gluten is present in the protein, hence, the flour may be made into porous bread. It will be recalled at this point that of the common small cereals, wheat and rye possess gluten, while oats and barley do not. The flour from rye is more starchy than that from wheat.

Germination of Rye.—Under favorable conditions, germination will take place in thirty-six to forty-eight hours.

By deep seeding, rye may send out roots and tillers at the second, third, or even fourth node. As a result rye can be planted deeper than wheat. The coleoptile is closed; the first leaf is rolled and brownish-red, which color distinguishes the rye seedling from other cereals.

Classification, and Origin of Rye.—The cultivated sorts of rye all belong to the one species, *Secale cereale*. This originated from *Secale anatolicum*, one of the subspecies of *S. montanum*. This stem form differs from *S. cereale* in the fragile rachis, the smaller, narrower fruit, and perennial rootstock.

Environmental Relations.—Rye is adapted to colder and drier climates than wheat, and will thrive on poorer soils and more sandy soils than any of the other cereals.

Uses of Rye.—Rye flour is made into bread. A few breakfast foods include rye as a minor component. Mixed with barley, or corn, or shorts, or oats, rye grain is fed to stock. In some sections it is grown for hay, or as a pasture crop, and

now and then as green manure. The straw finds considerable use as a stable bedding, as a packing material for nursery stock, as a stuffing for horse collars, and it is also used in the manufacture of paper strawboard, hats, and other coarse straw articles.

Production of Rye.—Russia produced 861,097,000 bushels of rye in 1915; Germany ranked second, with 470,000,000 bushels, Austria-Hungary third, with 154,075,000 bushels, and the United States fourth, with 49,190,000 bushels. The five leading States in the order of their production for the year 1919 are North Dakota, Michigan, Minnesota, Wisconsin and South Dakota.

References

BATALIN, A.: Das Perennieren des Roggens. Acta. Horti. Petropolitani, 11: 299–303, 1890. Also Verhandl. Bot. Ver. Brand., 32: 29–32, 1891.

RIMPAU, W.: Die Selbst Sterilität des Roggens. Landw. Jahrb., 6, 1877.

SCHULZ, AUGUST: Die Geschichte des Roggens. Jahresbericht des Westfälischen Provinzial-Vereins für Wissenschaft und Kunst (zu Münster) für 1910–1911, 39: 153–163, 1911.

Beitrage zur Kenntnis der kultivierten Getreide und ihrer Geschichte, I. Die Abstammung des Roggens. Zeitschr. Naturw., 84: 339–347, 1913.

TSCHERMAK, E.: Über künstliche Auslösung des Blühen beim Roggen. Ber. Deut. Bot. Gesell., 22: 445–449, 1904.

Das Blühen des Roggens (Secale cereale). Ostrk. Landw. Wchnbl., 1906, p. 163.

Die Blüh- und Fruchtbarkeitverhältnisse bei Roggen und Gerste und das Auftreten von Mutterhorn. Fuhlings Landw. Ztg., 55: 194–199, 1906.

ULRICH, C.: Die Bestäubung und Befruchtung des Roggens. Inaug. Diss., Jena, 1902.

WITTMACK, L.: Über die Stammpflanze des gemeinen Roggens, Secale cereale. Verhandl. Bot. Ver. Brand., 32: 32–34, 1890.

CHAPTER XIV

ZEA (Corn, Maize)

Roots.—Corn is distinctly a summer annual with a fibrous root system. Corn generally has been considered a shallow-rooted plant. The contrary is the case. At maturity the roots come to fill the upper 3 feet of soil and, under some conditions, may reach to a depth of 6 or 7 feet (Fig. 59). The depth of planting appears to bear no relation to the depth of rooting, for the first whorl of roots usually forms about 1 inch below the soil surface, no matter how deep the seed is planted. It will be remembered that this is true for the other cereals too. The roots of corn are thrown off in whorls, varying in number from two to ten, one whorl above another. The internodes between whorls are very short. The entire group of whorls constitutes the *root crown*.

Two kinds of roots are developed (Ten Eyck): (*a*) main vertical roots and (*b*) main lateral roots. Vertical roots curve out slightly from the crown and go directly downward. The laterals curve downward, as they leave the crown, then extend horizontally for a distance, finally taking a downward course. Laterals that leave the crown at about the soil level slope gradually downward, as indicated above. Midway between the rows of planted grain, about 22 inches from the hill, these laterals are about 4 or 5 inches below the soil level. The laterals may be shallower than given, in heavy soils and wet seasons. The roots of most plants are more superficial in a heavy or wet soil than in a light and drier soil. This is quite likely a response to oxygen supply, as well as to moisture supply. The amount of oxygen in the soil decreases as the depth increases. Moreover, the rate

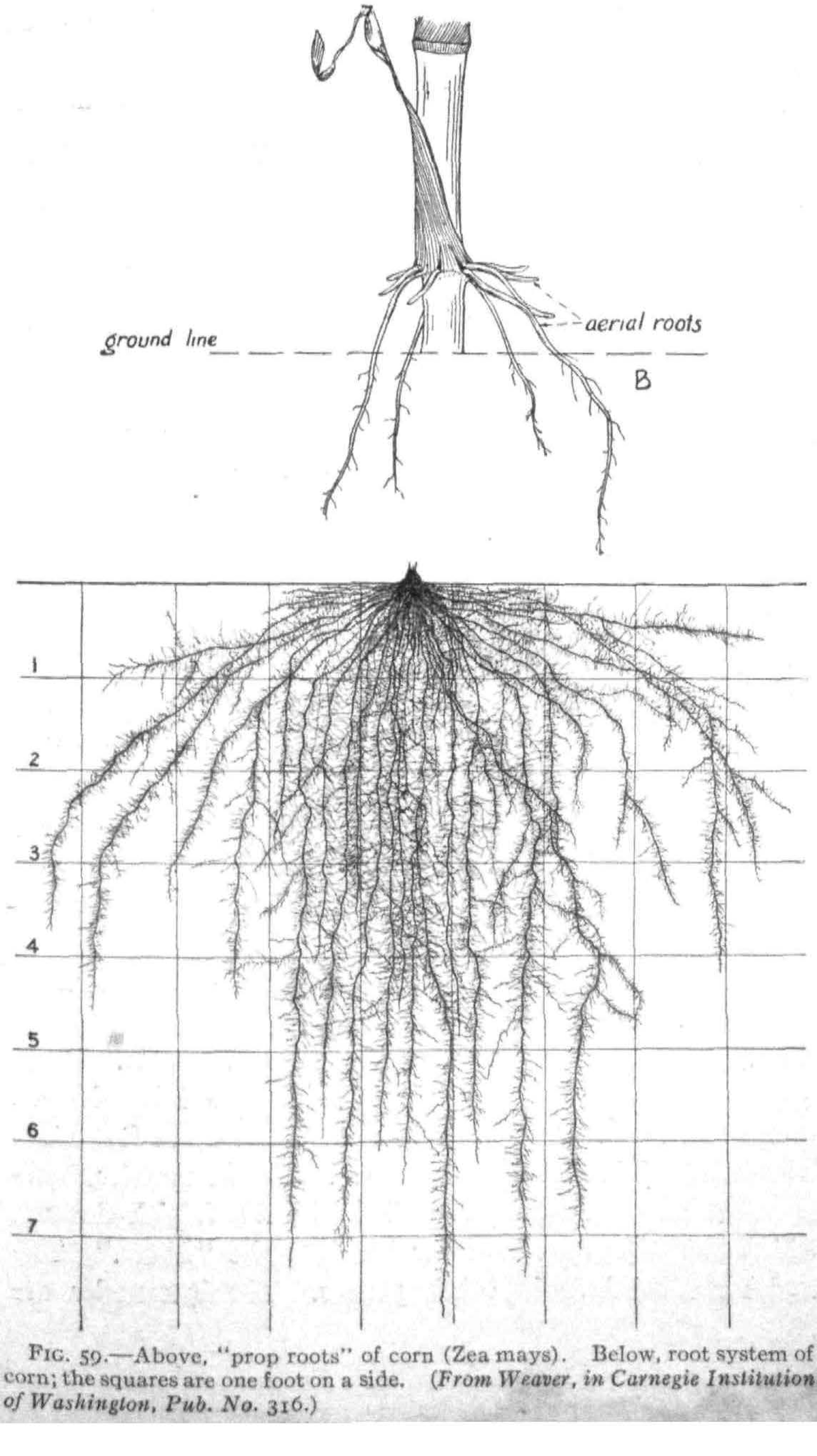


FIG. 59.—Above, "prop roots" of corn (Zea mays). Below, root system of corn; the squares are one foot on a side. (*From Weaver, in Carnegie Institution of Washington, Pub. No.* 316.)

of decrease is greater in heavy or wet soils than in light or dry soils. When it is understood that every living root cell derives its oxygen for respiration from the soil air immediately surrounding and that the oxygen does not diffuse to any extent from the aerial parts of the plant down through the stem to the roots, we see the probable explanation of the fact that a shallow root system is peculiar to a heavy or wet soil. In this connection, it should be stated that an important result of tillage is the loosening of the soil so that oxygen may more easily diffuse to the roots of the plant. All main roots give off numerous finer branches and these in turn branch, so that at maturity there is an interlacing mass of roots in the soil. It has been observed that, although the main laterals are several inches below the soil surface, they may send upward finer branches to within ½ inch of the surface. The depth of the corn roots determines the depth of cultivation. If it is so deep as to destroy roots, the yield is decreased.

"Prop" or "Brace" Roots.—In addition to the ordinary underground roots, corn develops aerial roots, the so-called "*prop*" or "*brace*" roots. These arise in whorls at successive levels above the surface, extending obliquely downward. They are covered with a mucilaginous substance which protects them from drying out. As aerial roots, they are unbranched, but they branch profusely when they strike the soil. They have the role of absorption, then, as well as anchorage.

Stem.—Corn is the largest of the common cereals. However, no other cereal varies so in size. There are dwarf forms scarcely 3 feet high, while some are 15 or more feet high. The stem is jointed as in all grasses. The internodes, however, are not hollow, but are filled with a soft pith through which run numerous vascular bundles, the "fibers." The nodes are solid as in other grasses. The internodes are

furrowed on the side next the leaf blade. The corn plant produces "*suckers*" which correspond to the "stools" of wheat, as to their morphology. "Suckers" are secondary stems or branches arising from the lower nodes. These branches develop their own roots. "Suckers" of corn are undesirable, for they do not, as a rule, produce ears, although they are heavy soil "feeders."

Leaves.—The leaves are arranged alternately on opposite sides of the stem as in all grasses. They vary in number from 8 to 20. The blade is long and flat; the ligule closely invests the stalk, acting as a rain-guard. Water that runs down the stem and leaf blade is prevented from entering the space between the culm and leaf sheath by this tightly fitting ligule.

The corn leaf is thrown into a number of folds along the edges and at the base. This is due to the more rapid growth of the cells at these points. The corn plant is moderately well adapted to dry conditions. An examination of the leaf structure explains this. On the upper surface of the leaf blade, along either side of the midrib, are a number of large wedge-shaped cells; these absorb water readily in moist weather, become turgid, and thus flatten the leaf out. In dry weather, these cells lose their turgor. Hence the leaf rolls up, presenting a smaller evaporating surface. In addition to this adaptation to dry conditions, the cuticle of the lower surface of the leaf is much thickened, and the water requirement of the plant is low as compared with oats, clover, or alfalfa. It has been computed that an average acre of well-adapted corn, grown at the Nebraska Agricultural Experiment Station, has 4 acres of leaf space, counting both sides.

Inflorescence.—Ordinarily, corn is monœcious, that is, the stamens and pistils are borne in separate inflorescences on the same plant (Fig. 60). The staminate flowers are in a

panicle at the top of the stalk; this inflorescence is known as the "*tassel*." The pistillate flowers are borne in a spike which is placed in the axil of a leaf lower down on the stem.

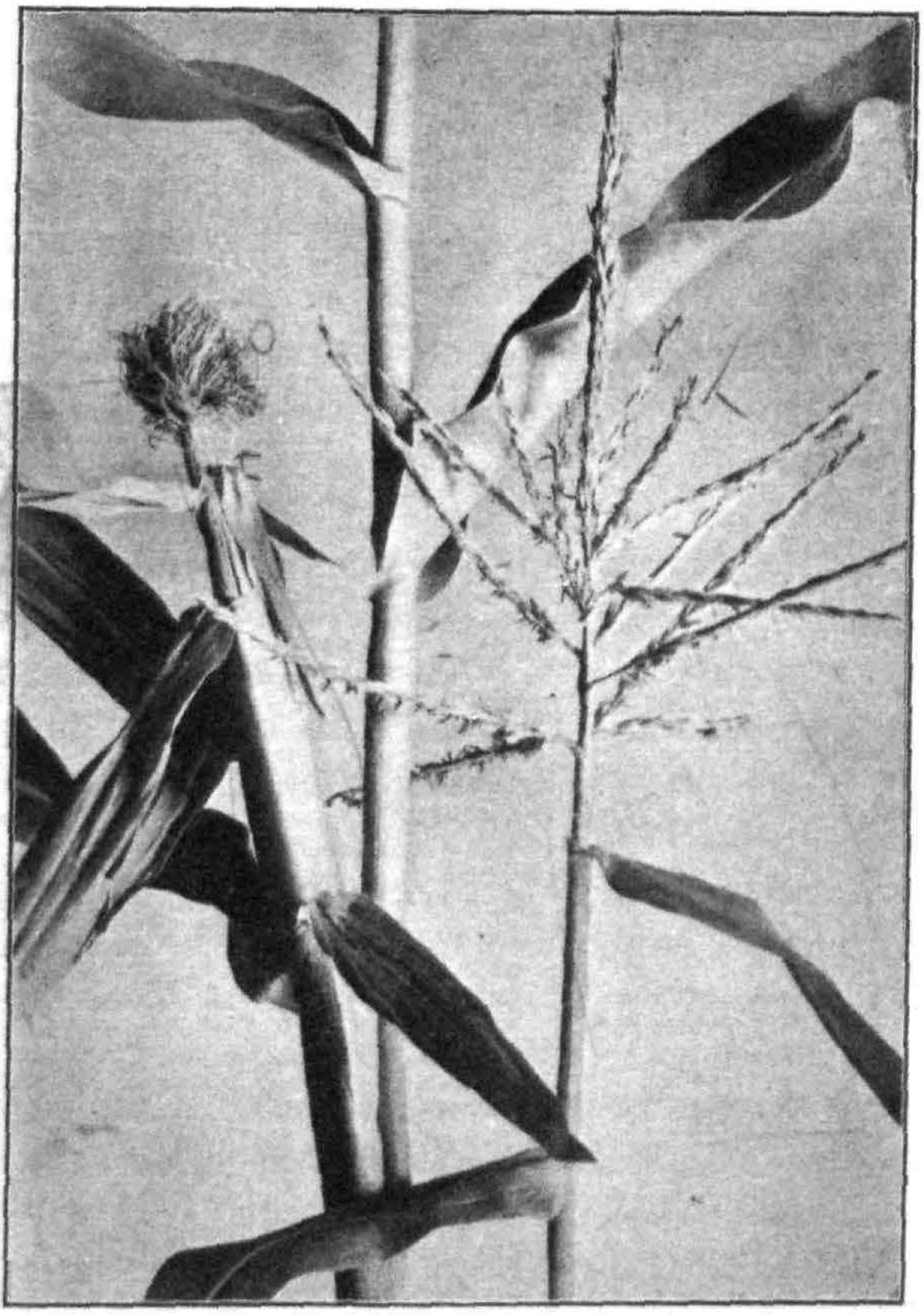


FIG. 60.—Pistillate and staminate inflorescences of corn (Zea mays).

When mature, the pistillate inflorescence is called the "*ear*."

Staminate Inflorescence ("tassel").—The rachises of the panicle are long, slender, and spike-like. One may distinguish between the central and lateral spikes of the panicle.

In the central spike (Fig. 61), there are usually from four to eleven rows of spikelets, in pairs. Lateral branches usually have only two rows of spikelets in pairs. One spikelet of each pair is pedicellate, the other sessile (Fig. 62), or in some cases both may be sessile. The groups of spikelets may overlap.

FIG. 61.—A single branch of the staminate inflorescence of corn (Zea mays).

Staminate Spikelet.—Each normal staminate spikelet bears two flowers, each producing three perfect stamens and a rudimentary pistil (Fig. 63). The glumes are seven- to twelve-nerved, and about equal in size. The lemma is three- to five-nerved and the palet two-nerved. The two lodicules are fleshy and truncate. The anthers are long. The upper flower of a spikelet matures first; its palet is larger than the lemma, while in the lower flower, the lemma is larger than the palet.

Pistillate Inflorescence ("ear") *General Characteristics.*—The ear (Fig. 64) is borne on a short branch, the so-called "shank." This branch consists of a number of very short internodes with one modified leaf at each node. The blades of the modified leaves have been reduced, the leaf sheaths alone remaining. The collection of leaf sheaths on the shank forms the "husk" of the ear. The pistillate spikelets are arranged in rows along a fleshy axis, the "cob."

What Is the "Ear," Morphologically?—There are two theories as to the morphology of the ear of corn. The view of Hackel and of Harshberger is that the

ear is the result of a fusion of a number of two-rowed pistillate spikes. Since each spikelet is two-flowered, and the lower abortive, there are often formed the two distinctly paired rows. The cob is said to be formed by the fusion of

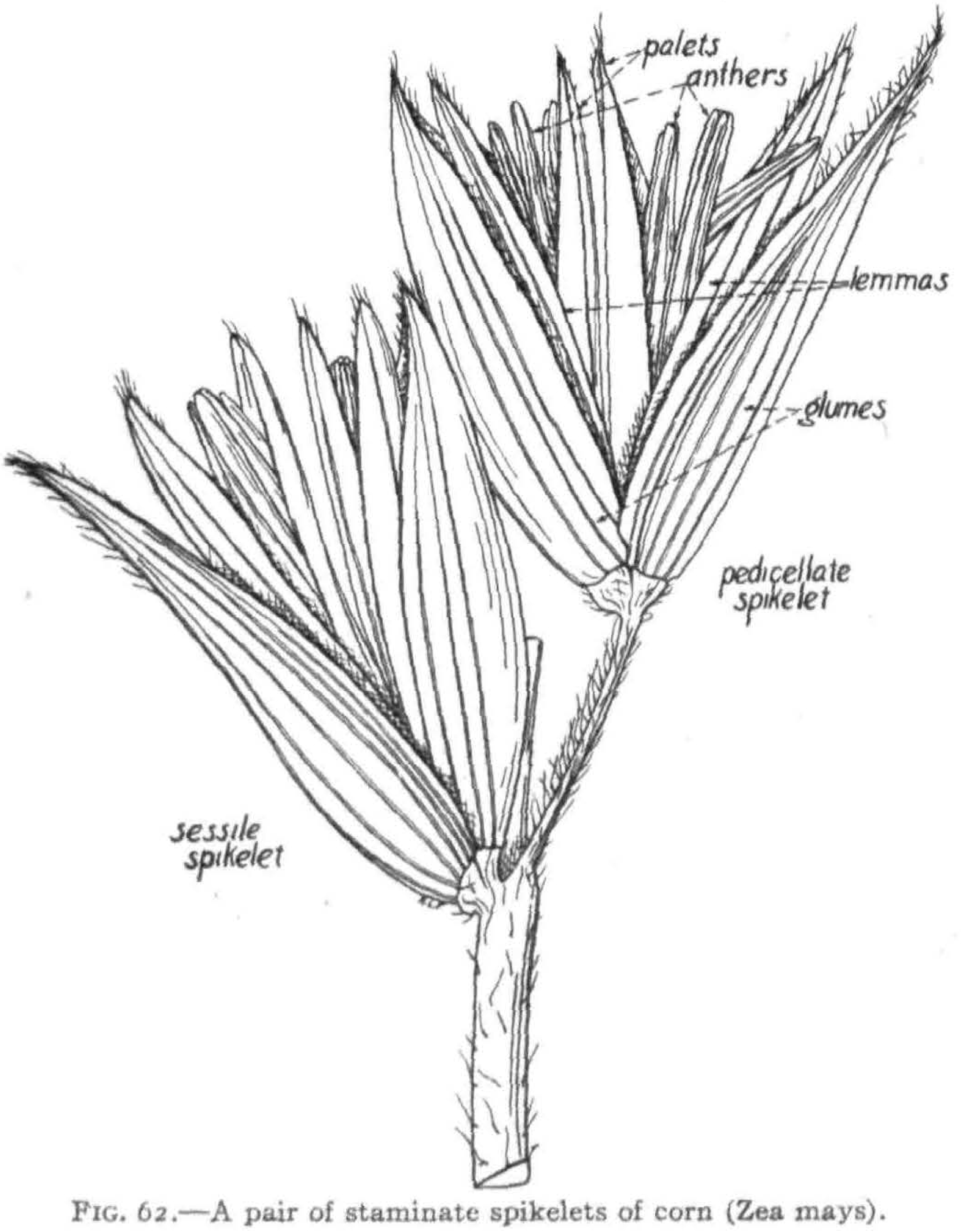


FIG. 62.—A pair of staminate spikelets of corn (Zea mays).

separate rachises. Opposed to the above theory is that of Montgomery, who holds that the ear develops "directly from the central spike of some tassel-like structure similar to the

well-known corn tassel." His evidence for this belief may be summarized as follows:

1. He has found tassels in which a few pistillate flowers were found on the central spike, also tassels in which the central spike had developed into a fair-sized ear of corn.

2. He observed a case in which the lateral spikes as well as the central one had developed pistillate flowers, forming a number of four-rowed "nubbins" surrounding a central well-developed twelve-rowed ear.

3. The central spike develops pistillate flowers much more readily than the lateral ones of the tassel. The central spike has the greater number of rows of spikelets.

4. He has observed the development of pistillate flowers from staminate ones. This development is as follows:

(*a*) Pedicellate spikelet shortens and becomes sessile; the difference between the two flowers of this becomes greater.

(*b*) The lower glume shortens and thickens.

(*c*) Lemma and palet of upper flower become reduced while the lower flower becomes abortive.

(*d*) Sessile flower becomes pistillate.

(*e*) Both flowers become pistillate.

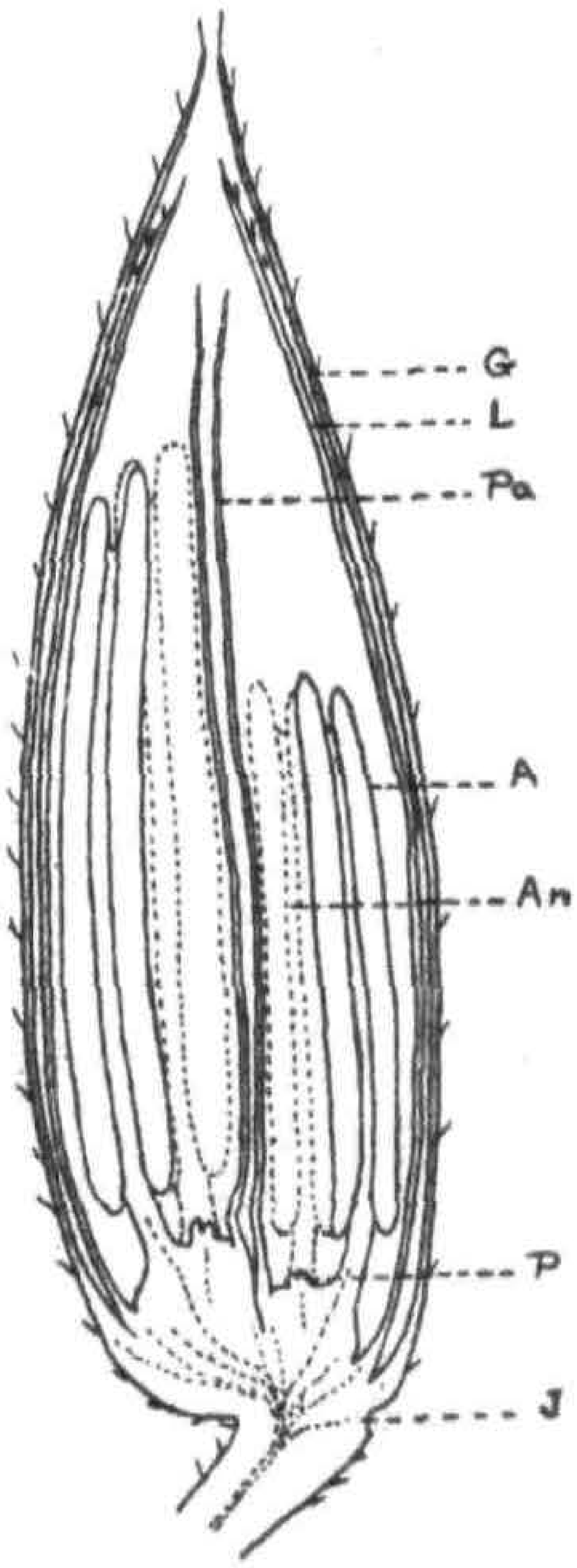


FIG. 63.—Longitudinal section of staminate spikelet of Country Gentleman sweet corn, × 15. *G*, glume; *Pa*, palet; *An*, position of one of the lateral anthers; *L*, lemma; *A*, dorsal anther. *P*, rudimentary pistil; *J*, joint of rachilla. (*After Weatherwax.*)

Recently East and Hayes have expressed an opinion very similar to that of Montgomery. Quoting from them, "The ear of maize, then, is a meristic variation produced from the central spike of the tassel of the lateral branches of teosinte

or of a teosinte-like plant, and not a fusion of the lateral spikelets." Montgomery suggests that teosinte and corn had a common ancestor, which was a "large, much-branched grass, each branch being terminated by a tassel-like structure,

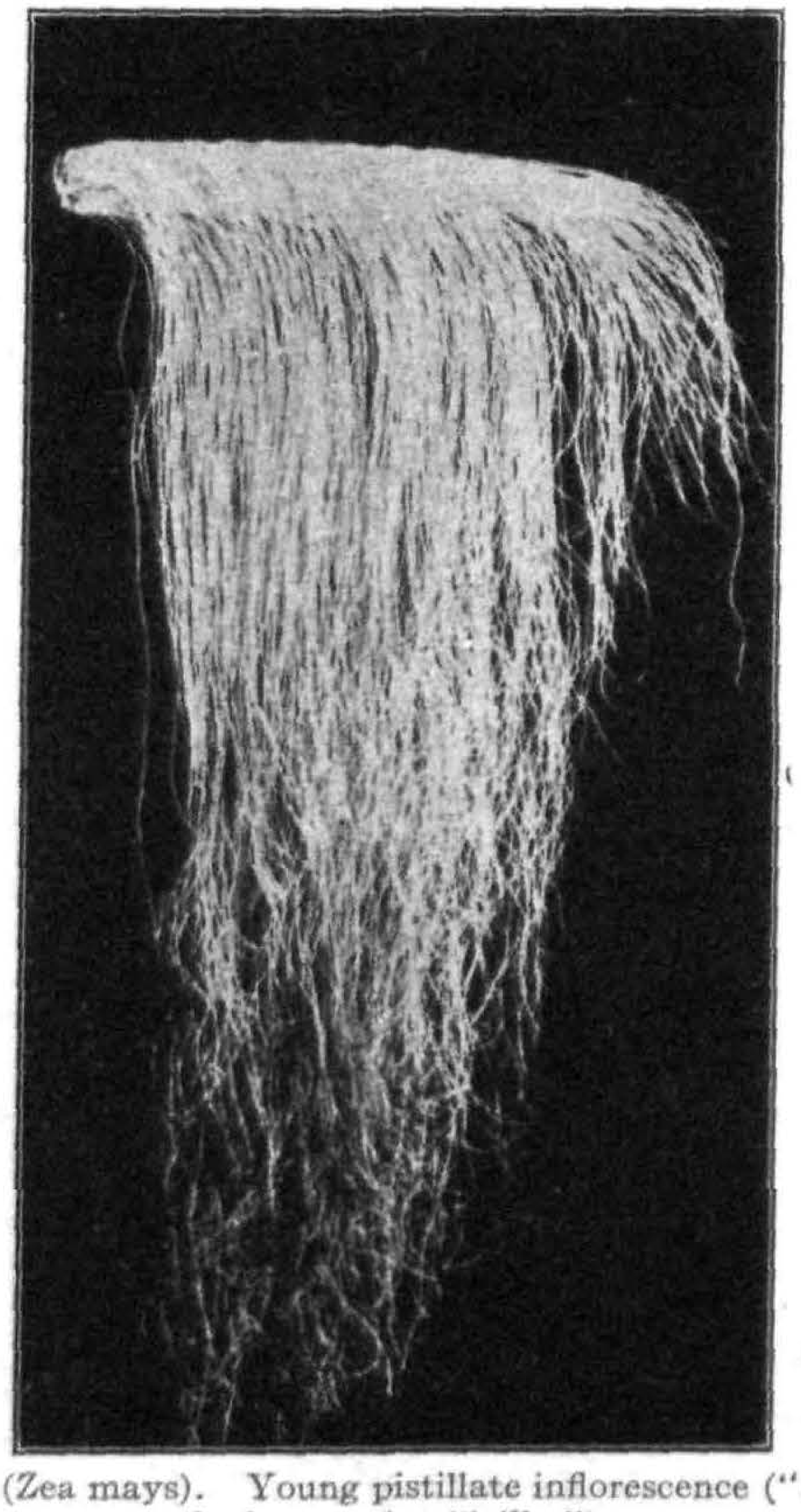


FIG. 64.—Corn (Zea mays). Young pistillate inflorescence ("ear"), showing the long styles ("silks").

bearing hermaphrodite flowers." He says further: "As evolution progressed, the central tassel came to produce only staminate flowers, these being higher and in a better position to fertilize the flowers on the lower branches. At the same

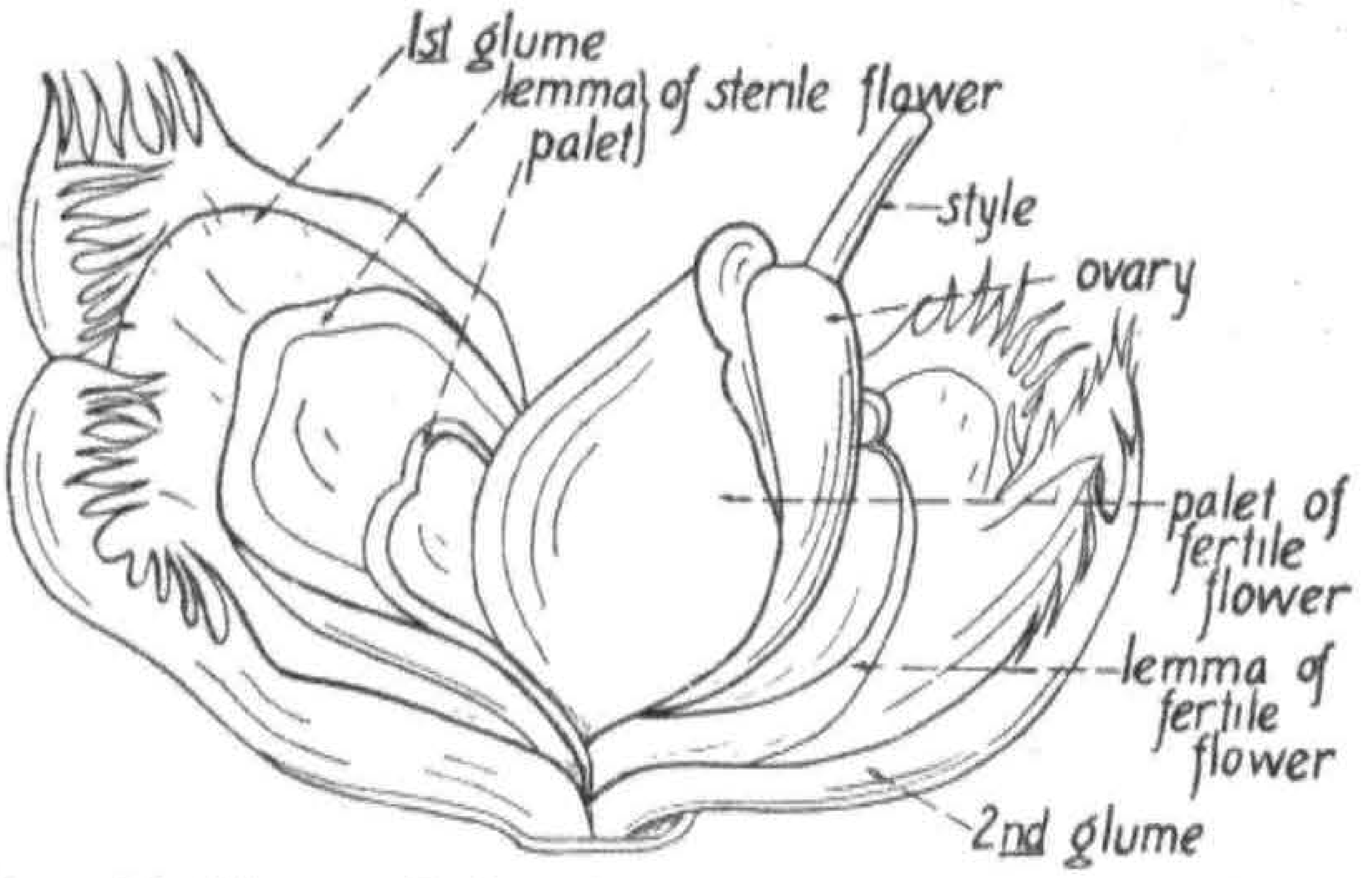


FIG. 65.—Pistillate spikelet of corn, much enlarged. (*After Nees.*)

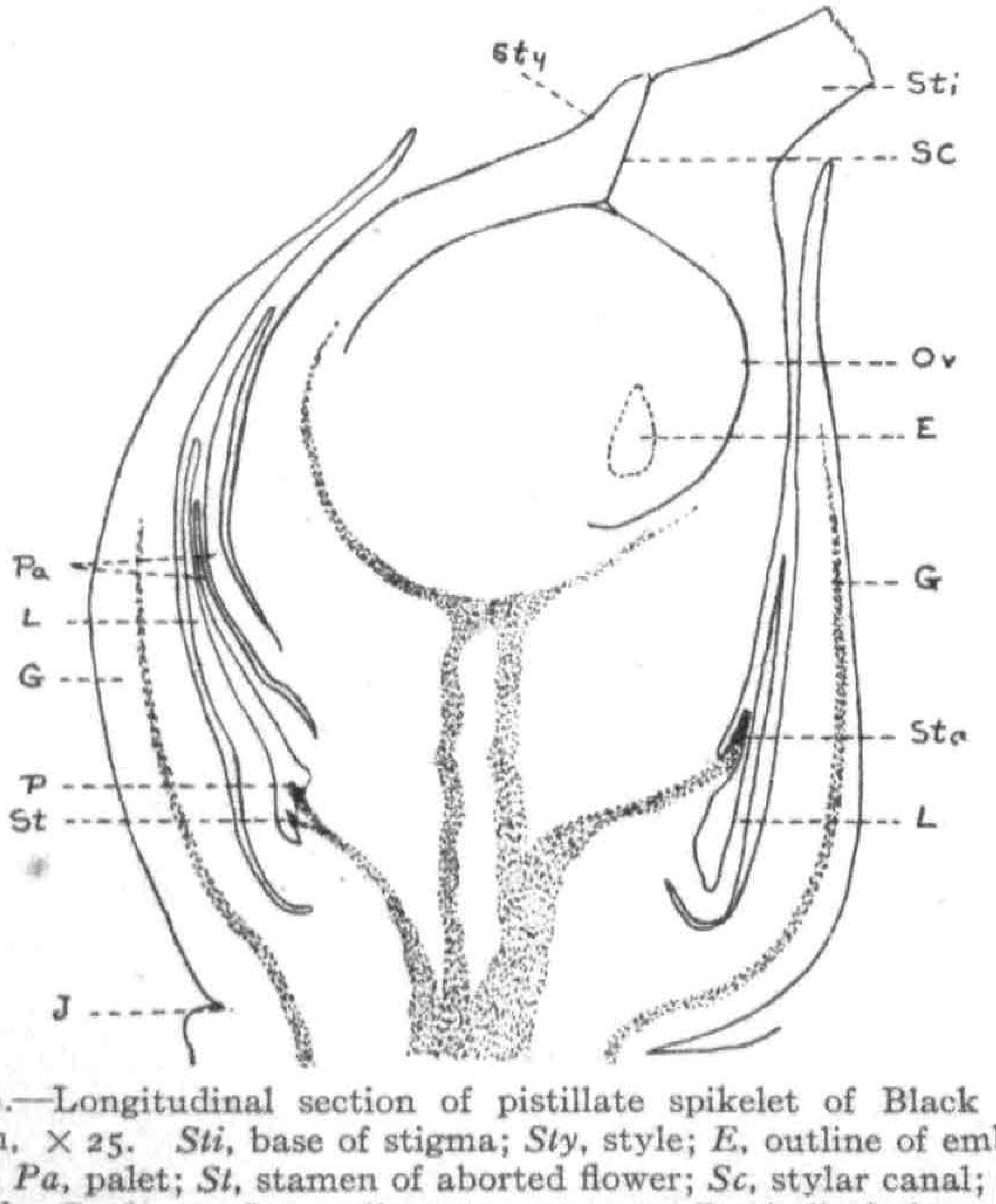


FIG. 66.—Longitudinal section of pistillate spikelet of Black Mexican sweet corn, × 25. *Sti*, base of stigma; *Sty*, style; *E*, outline of embryo sac; *L*, lemma; *Pa*, palet; *St*, stamen of aborted flower; *Sc*, stylar canal; *Ov*, functional ovule; *G*, glume; *Sta*, rudimentary stamen; *P*, pistil of aborted flower; *J*, joint of rachilla. (*After Weatherwax.*)

time, the lateral branches came to produce only pistillate flowers, their position not being favorable as pollen producers, while, on the contrary, they were favorably placed to receive pollen. This differentiation in the flowers was accompanied by a shortening of the internodes of the lateral branches until they were entirely enclosed in the leaf sheaths" (the husks).

Pistillate Spikelet.—Each normal pistillate spikelet has two flowers, the lower one of which is abortive[1] (Figs. 65 and 66). The palet and lemma of the abortive flower remain, and form a part of the "chaff" on the cob. The spikelet is subtended by two glumes that are shorter than the ovary, very broad and fleshy at the base, thin membranous above and fringed on the edges. The lemma and palet of the fertile flower are short, broad and membranous. In pod corn, glumes, lemma, and palet attain a considerable size and enclose the grain. The single ovary bears one long style, the corn "silk," which is forked at the tip. It is well to remember that there is one silk for each grain on the cob. The corn silk is considered to be a compound stigma rather than a style. The silk is indeed receptive to pollen a good portion of its length, possibly all. A hot, dry wind may wither the silks, thus destroying their receptivity to pollen. Fertilization of the ovules consequently does not take place, and the ovules do not mature. At the top of the ovary and near the base of the style is a short protuberance, which has a funnel-shaped depression in its center. This depression marks the position of a former opening in the ovary wall, termed the *stylar canal.* which becomes closed during development of the ovary. Three small rudimentary stamens have been

[1] Stewart has noted, in the Country Gentleman variety of corn, that some spikelets bear two well-developed flowers inside each pair of glumes. He further points out that the irregularity in the arrangement of grains on the ear may be due to the development of the second flower in some of the spikelets, which tends to throw some of the grains out of line. The same has been noted by Sturtevant and Kempton.

observed in the fertile flower; the lodicules are absent. The small aborted flower has rudimentary stamens and pistil about equally developed; the lodicules are present.

Hermaphroditic Flowers.—Ordinarily in corn the flowers are imperfect, that is either staminate or pistillate. Perfect or hermaphroditic flowers sometimes occur, however. Hermaphroditic flowers are far more common on the tassel than on the ear. East and Hayes record a sterile dwarf mutation which had nothing but hermaphroditic flowers. Hermaphroditic flowers have the stamens reduced. Lodicules are well developed in staminate flowers, reduced in hermaphroditic flowers, and altogether absent in fertile pistillate flowers. Hermaphroditic flowers have been observed on normal types of ears. The plants from these seeds came true to type. The seed was normal in every respect except that it had three fully developed stamens coming from near the base of the ovary. There were also three small stamens in the aborted flower of each pistillate spikelet. The plants were of unusual appearance, being 5 feet high, with short internodes and broad leaves.

Opening of the Flowers, and Pollination.—Cross-pollination, consequently cross-fertilization, is the rule in corn but self-fertilization frequently occurs. Wind and gravity are the chief factors in pollen dissemination, although bees visit the flowers and are evidently concerned in pollen dispersal; they are relatively of far less importance than wind.

In the case of the staminate inflorescence, the first flowers to open are those near the upper part of the central spike; blooming spreads both upward and downward, more rapidly downward. The same order of blooming occurs on the branches of the tassel.

The time of pollen shedding depends upon weather conditions. Cold, wet, weather retards or even prevents the shedding of pollen. On the other hand, droughty conditions

hasten the shedding of pollen, but delay the appearance of silks. Hence it may happen that under these conditions much of the pollen is scattered before the stigmas are protruded and receptive, and an incomplete filling of the ear results. On sunshiny days, most of the pollen is shed during the forenoon and, in some instances, late in the afternoon of the same day. Individual tassels usually remain in blossom from four to ten days or even more, depending upon the weather. Furthermore, the anther does not shed all its pollen as soon as it opens, but discharges it a little at a time. In investigating a number (59) of varieties of corn as to the time elapsing between the appearance of anthers and appearance of first silks, Gernert finds marked variation. Both *dichogamy* (maturation of pollen and stigmas at different times) and *homogamy* (simultaneous maturity of pollen and stigmas) may occur. Furthermore, in dichogamous individuals, protandry (anthers mature first) or protogyny (stigmas mature first) may occur. Out of 2,794 individuals in 59 varieties examined, he found 243 individuals homogamous, 92 protogynous, and 2,459 protandrous. It appears, then, that protandry is the rule in corn. In protandrous individuals, the first appearance of silks occurred from one to twenty-three days after pollen shedding, although the average is two days. Varieties of corn dealt with in the above were pod, pop, flint, dent, soft, and sweet. There is record of the discovery of the protogynous habit in a variety of maize introduced from Granada, Spain. Ordinarily, however, dichogamy is seldom pronounced enough to completely exclude self-pollination.

Gernert has also made observations as to the number of days intervening between the appearance of tassel and anthers. He finds, out of 3,319 individuals in 57 varieties, that, in the greatest number (514), the anthers appeared nine days after the tassel, and that in more than half of the

individuals the first anthers appeared in seven to ten days after the tassels bearing them appeared.

Pollen is produced in great quantities. It is estimated that each tassel produces 20,000,000 to 50,000,000 grains of pollen and that for each ovule in dent maize there are about 45,000 pollen grains produced.

The size of pollen grains in corn varies. Pollen produced by central spikes is larger than that produced by laterals. It has been observed that in Leaming corn the pollen grains from the central spikes were 0.02 millimeter larger on the average than those from lateral spikes. Of 12 varieties examined, Gernert finds that the average diameter of the pollen grain of corn varies from 0.08 to 0.1 millimeter. They vary in shape from spherical to ellipsoidal. Corn pollen soon shrivels after being shed, but its germinating power is not destroyed by this. However, pollen does not remain viable much longer than twenty-four hours after shedding.

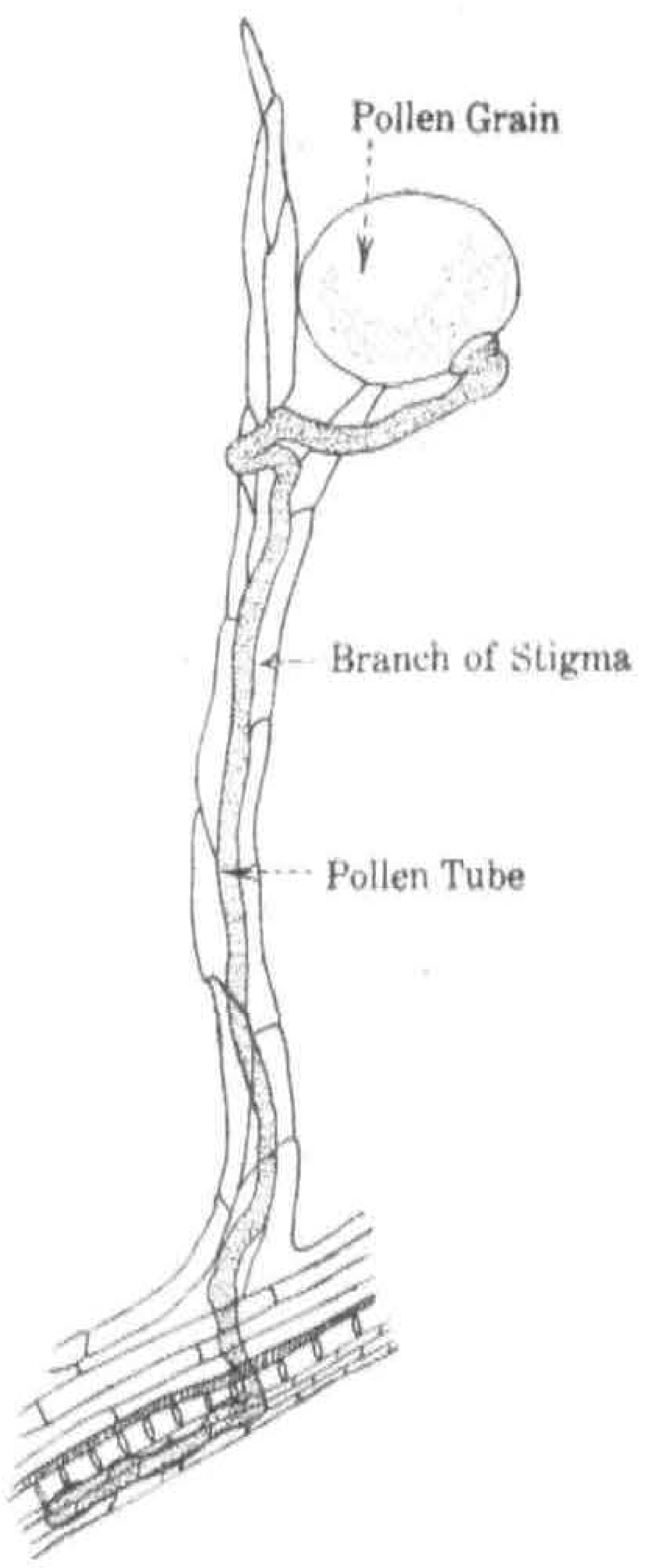


FIG. 67.—Germinating pollen grain of corn. (*From Holman and Robbins, after Miller.*)

Corn "silks" are long and plumose. They bear numerous hairs, which are more numerous near its tips than farther down. Miller states that "practically all pollen tubes that function are from pollen grains that fall on the hairs of the silk," rather than from those which fall directly on the smooth portion of the silk. The first silks to appear on the ear are those from grains slightly above the base. Generally, four or five days intervene between the appearance of

lowest and uppermost silks. Hence, it will require four or five days to pollinate all the silks of an ear. Unfavorable climatic conditions, such as cold, wet weather or extremely hot days, may account for the incomplete "filling out" of ears.

The silks are receptive throughout their length. Best results are obtained when silk receives the pollen within a few days after its emergence from the husk. Silk exposed by splitting down the husks proved receptive. Again, fertilization is not prevented when tips of silks are cut off.

A large number of pollen tubes start down any given silk, but by the time the ovary cavity is reached, the number is reduced to one.

Fertilization, and Development of the Grain.—Just prior to fertilization, the ovary of corn is bent from the perpendicular so that the silk, instead of pointing directly out from the cob, points in a direction longitudinal to the cob. The ovary is on a stalk (rachilla) about 2.5 millimeters long. The ovule almost fills the ovary cavity. It is attached to the wall of the ovary by more than one-third its circumference. The outer integument is incomplete while the inner covers the entire ovule, except the micropyle. This opening is just above the point of attachment of the lemma. Fertilization may occur in from 26 to 28 hours after pollination.

The ovary wall at this time, that is before fertilization, possesses the following coats:

1. Single row of epidermal cells.

2. Many layers of parenchyma tissue, varying somewhat in size.

3. Single layer of inner epidermal cells.

The presence of a pit "a short distance from the base of the style, on the posterior side," has been recorded, which is probably the "stylar canal."

The outer and inner integuments vary in thickness from two to four layers. The very large embryo sac is located at the base of the nucellus.

After fertilization, the following changes take place in the maturing grain:

1. Outer integument disappears.
2. Cells of inner integument become flattened, due to pressure from within.
3. The middle and inner cells of pericarp become compacted.
4. Cells of nucellus disappear to a large extent.
5. Hardening of the cell walls of the pericarp.
6. Fusion of pericarp and inner integument.

Xenia in Corn.—Xenia is the term applied to the phenomenon in which some character of the male appears at once in the seed. For example, in crossing a strain of corn having yellow endosperm with a strain having white endosperm, the grains produced are all yellow in every case, no matter which is used as the male parent. Xenia is shown only in case the parent having yellow endosperm is used as the male parent. The yellow endosperm character is dominant over white endosperm. Pollen from the plant bearing yellow endosperm will carry this character; pollen from the plant bearing white endosperm will carry the white character. When pollen, bearing the yellow endosperm character, is placed on the stigma of the grain having white endosperm, the pollen tube will discharge into the ovule two male nuclei, each bearing the character for yellow endosperm. One sperm nucleus fuses with the egg nucleus, the other sperm nucleus fuses with the two polar nuclei. The result of this triple fusion (second sperm nucleus and two polar nuclei) is the endosperm. Now, since yellow is dominant, the grain that is formed by this double fertilization will have a yellow endosperm. Thus double fertilization explains

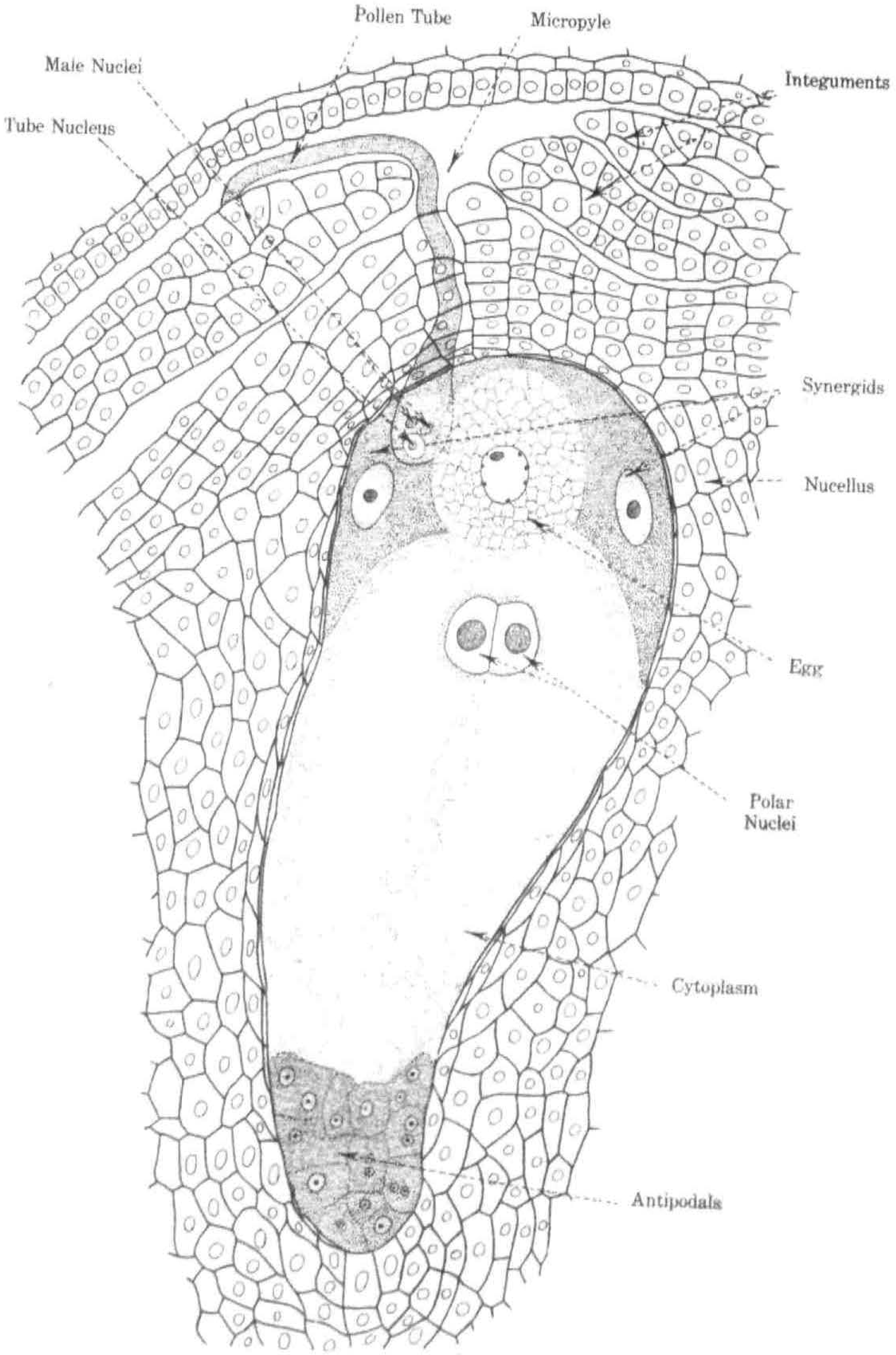


FIG. 68.—Mature embryo sac of corn (*Zea mays*). (*From Holman and Robbins, after Miller.*)

the phenomena of xenia. It is of course true that, if in the above, pollen from the white endosperm-bearing plant were used, xenia would not be shown. Xenia, the visible effects of double fertilization, has been found in the following conspicuous cases in corn—in each case below, the plant mentioned first is the female:

Non-starchy-seeded plants crossed with starchy-seeded plants always give starchiness.

Non-yellow endosperm crossed with yellow shows yellow.

Non-colored aleurone layer crossed with purple gives purple.

Non-colored aleurone layer crossed with red gives red.

Variation in the Corn Plant.—There are marked individual differences in the plants of an ordinary field of corn. The plants may vary in height, vigor, leaf production, height of ears on the stalk, shape of ears, composition of kernel, etc. There is a wide range of variation in the number of rows of kernels on the ear. In the flint varieties, Black Mexican Sweet and Golden Bantam Sweet, the characteristic number is eight. Some of the larger sweet and dent varieties will have as many as 24 or 26 rows. The Country Gentleman sweet corn may bear ears with an odd number of rows, which is undoubtedly due to the development occasionally of both flowers of a paired spikelet. Moreover, there is scarcely any other crop plant in which we find more abnormalities or monstrosities than we do in corn. We have mentioned hermaphroditic flowers, both in the tassel and ear as one abnormality; to these we may add branched ears tassels with a few or many kernels, variegated leaves, and variegated ears, white or yellow seedlings, and dwarf plants. In corn it is possible for the different kernels of an ear to receive pollen from many different plants, and from its own tassel. Hence, it usually happens that the grains on the same ear have different hereditary characters as shown by

their varied progeny. This is well shown in variegated ears. If xenia occurs, the effects of this crossing may be evident the same season. For example, if pollen from dent corn fertilizes some of the ovules on an ear of sweet corn, those ovules appear starchy, while the other grains of the ear of corn, fertilized with sweet corn pollen are wrinkled. If xenia does not occur, the results of the mixing will not show up until the second year. Hence, ordinarily even though an ear of corn appears uniform, the separate kernels may have

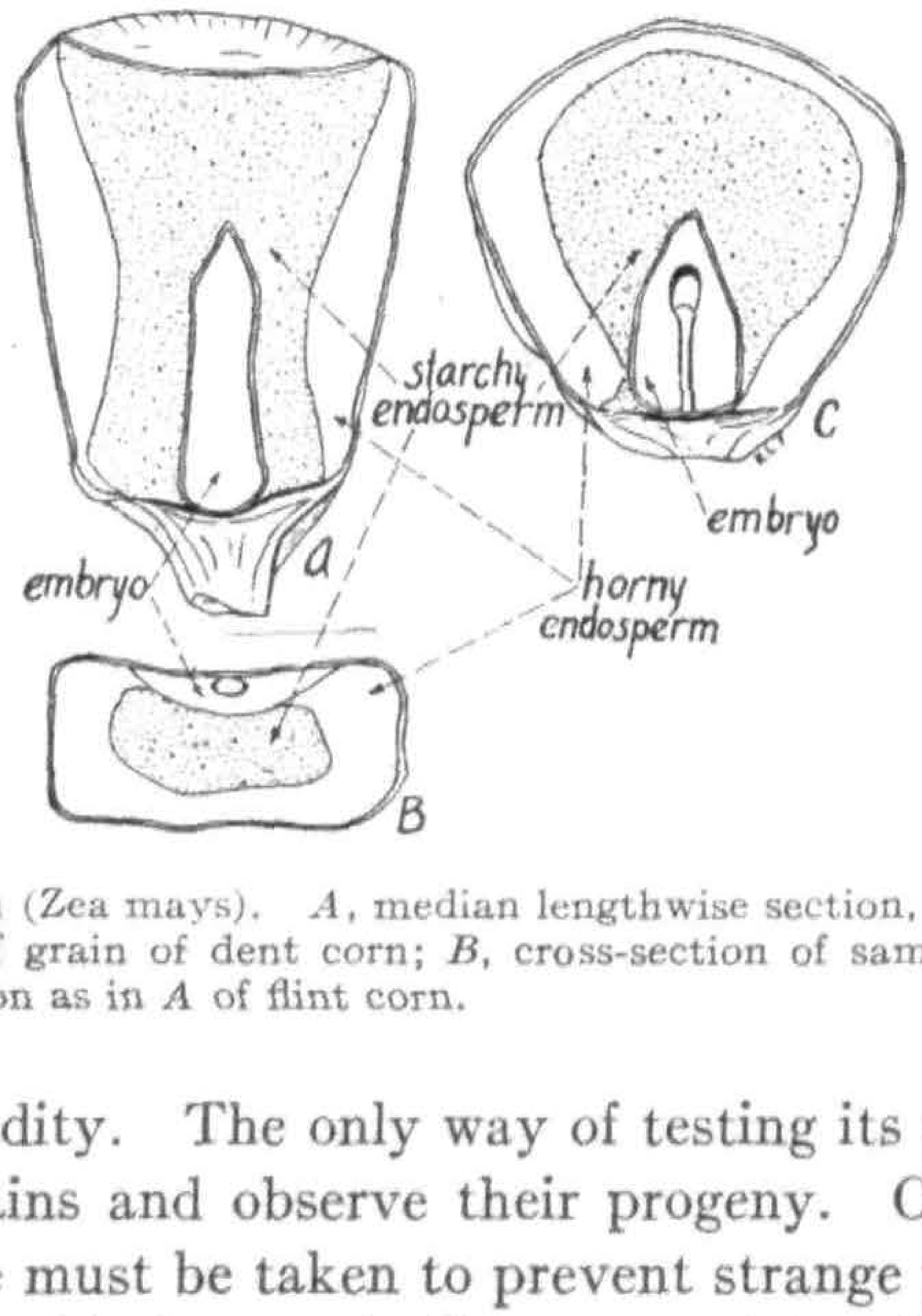


FIG. 69.—Corn (Zea mays). *A*, median lengthwise section, cut parallel to broad surface, of grain of dent corn; *B*, cross-section of same through the embryo; *C*, section as in *A* of flint corn.

different heredity. The only way of testing its purity is to plant the grains and observe their progeny. Of course in this test, care must be taken to prevent strange pollen from blowing in. This is practically accomplished by isolating the test plots.

Results of Self-fertilization in Corn.—If our ordinary field strains of corn are self-fertilized for several generations the yield is considerably reduced. However, as a result of this inbreeding, we may be sure that all the kernels on an ear

have the same hereditary qualities. Furthermore, artificial self-fertilization for five or more successive years results in a strain that is not so complex in its characters, that is, a race which is comparatively uniform and pure.

The Mature Grain of Corn.—The mature grain of corn varies considerably in shape (Fig. 69). In most varieties, it is flattened in a plane at right angles to the length of the cob. The broader surface is roughly triangular in outline, being broader above than at the base. The groove indicates the position of the embryo. At the "tip" of a mature grain, may still be found the papery remains ("chaff") of the palet, lemma, and glumes of the pistillate spikelets. The point of the grain, where it was attached to the cob, is the *peduncle* of the flower. The opposite indented end of the grain is often marked by a small point which is the remnant of the style. A longitudinal section of the corn grain parallel with the broad surface will show, with magnification, the following parts.

1. *Pericarp*, of several layers.
2. *Testa, inner integument,* of two layers.
3. *Nucellar tissue.*
4. *Aleurone layer*, outermost layer of endosperm, a single row of cells.
5. *Starchy endosperm.*
6. *Horny endosperm.*
7. *Embryo.*
8. *Tip cap.*

The pericarp and testa form the *hull.* It is possible to separate mechanically the starchy endosperm into two parts, the *crown starch* and *tip starch.*

The following is a fair average of the relative proportions of the divisions of the grain, as given by Hopkins, Smith, and East:

	Per cent.
Embryo	11.0
Tip cap	1.5
"Hull"	6.0
Aleurone layer	8.0 to 14.0
Horny endosperm	45.0
Starchy endosperm	25.0

Of course, there is a marked variation in the proportions of these parts, and in their chemical composition.

Chemical analysis of the above parts shows that the hull contains less protein (about 4 per cent.) than any other part

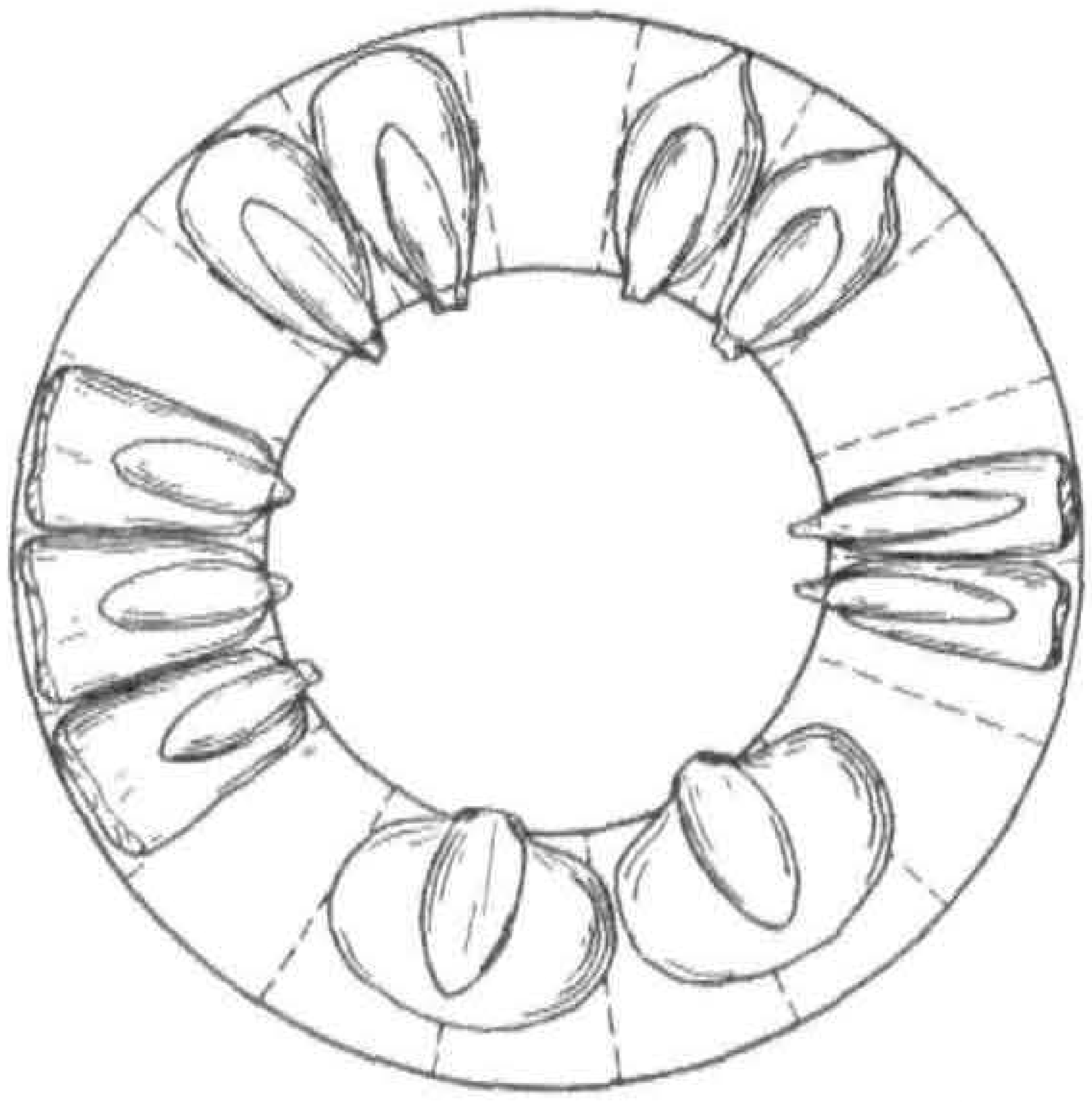


FIG. 70.—Variation in the shape of corn grains. Which is the best proportioned kernel? Why? (*After Mich. Agr. Exp. Sta. Bull.* 34.)

of the grain. The endosperm is richest in protein, containing 20 to 25 per cent. The horny endosperm contains about 90 per cent. starch and 10 per cent. protein. The starchy endosperm is poor in total amount of protein (5 to 8 per cent.). The germ is rich in oil, being composed of about 35 to 40 per cent. of oil and 19 to 20 per cent. protein. As much as 80 to 85 per cent. of the total oil content of the kernel occurs in the embryo.

In high-protein corn kernels, the horny endosperm extends up to and comes into contact with the embryo, the tip starch being entirely separated by it from the crown

starch. In low-protein corn kernels, the amount of horny endosperm is reduced, tip and crown starch being continuous between it and the embryo. The embryo is much larger in high-oil kernels than in low-oil kernels.

Embryo.—In the normal flower, the embryo of corn is on the side of the grain toward the tip of the ear. Inverted grains have been found, however. This inversion is due to the development of the lower flower of the pair in the pistillate spikelet. The embryo has the same structure as that of wheat. On account of its large size, the parts are readily made out. Its structure is best studied in a longitudinal section cut at right angles to the broad surface. The primary root is conspicuous; the two laterals may be recognized as two swollen areas near its base. The scutellum, or single cotyledon, is traversed by a vascular system. The hypocotyl is just beneath the plumule, being terminated at its base by the primary root.

Color.—Purple, blue, black, and red grains owe their color largely to a pigment located in the sap of aleurone cells. In some grains, there is a red sap in the pericarp. There is an absence of pericarp, aleurone and endosperm colors in white corn. In yellow maize, the coloring matter occurs both in the aleurone layer and in the endosperm.

Corn Starch Distinguished from the Other Common Starches.—The following key, adapted from Winton's Microscopy of Vegetable Foods, gives the characteristic microscopic differences between the common commercial starches.

All or most of the grains rounded, not from aggregates.
- Grains rounded, with central hilum; small grains globular or angular, *Wheat.*
- Grains large, of various shapes, with excentric hilum, *Potato.*

Grains polygonal or rounded, with one or more facets, mostly from aggregates.
- Grains very small, sharply angular, *Rice.*
- Grains large, polygonal or rounded; hilum with clefts, *Maize.*

Germination of Corn.—The optimum germinating temperature of corn is somewhat higher than that of the common small cereals. Whereas the latter will germinate at a temperature of melting ice, there is a marked decrease in the germination of corn at a temperature of 45° to 50°F., and at 40°F., it fails to germinate altogether. In germination, the primary root appears first, at the tip of grain; soon the plumule breaks through the pericarp at about the middle of the grain. The young germinating grain consists of a primary root projecting at the peduncle end, and the plumule emerging through a slit in the pericarp at about the middle of the grain, and pointing in the opposite direction. On the sides of the primary root, usually two secondary ones soon appear, making a total of three roots in the *primary root system.* In the dent corns, four temporary often occur, and often in flint and sweet corns there is but one temporary root.

In the seedling, there is, as in other cereals, a more or less elongated axis between the base of the coleoptile and the grain. This has been named the mesocotyl by some morphologist. Collins described seedlings of maize grown by the Indian tribes of the southwestern United States, that may develop, under conditions of deep planting, a mesocotyl up to 36 centimeters in length.

Classification.—The many different varieties of cultivated corn are all included under the one name, *Zea mays* L. Sturtevant has divided this species up into "species groups" (subspecies), the most important of which are the following:*

1. *Zea tunicata*, pod corn.
2. *Zea everta*, pop corn.
3. *Zea indurata*, flint corn.
4. *Zea indentata*, dent corn.
5. *Zea amylacea*, soft corn.
6. *Zea saccharata*, sweet corn.

* The specific name "mays" is omitted, for convenience.

7. *Zea amylea-saccharata*, starchy sweet corn.

Gernert describes a type of corn with branching ears and highly branching tassels, which he considers as a distinct subspecies and for which he suggests the name *Zea mays ramosa*. Collins describes a new type of Indian corn from China. This has erect leaf blades, some upper leaves arranged in a monostichous manner, silks developing inside the leaf sheath, and grains with a peculiar waxy endosperm. *Zea*

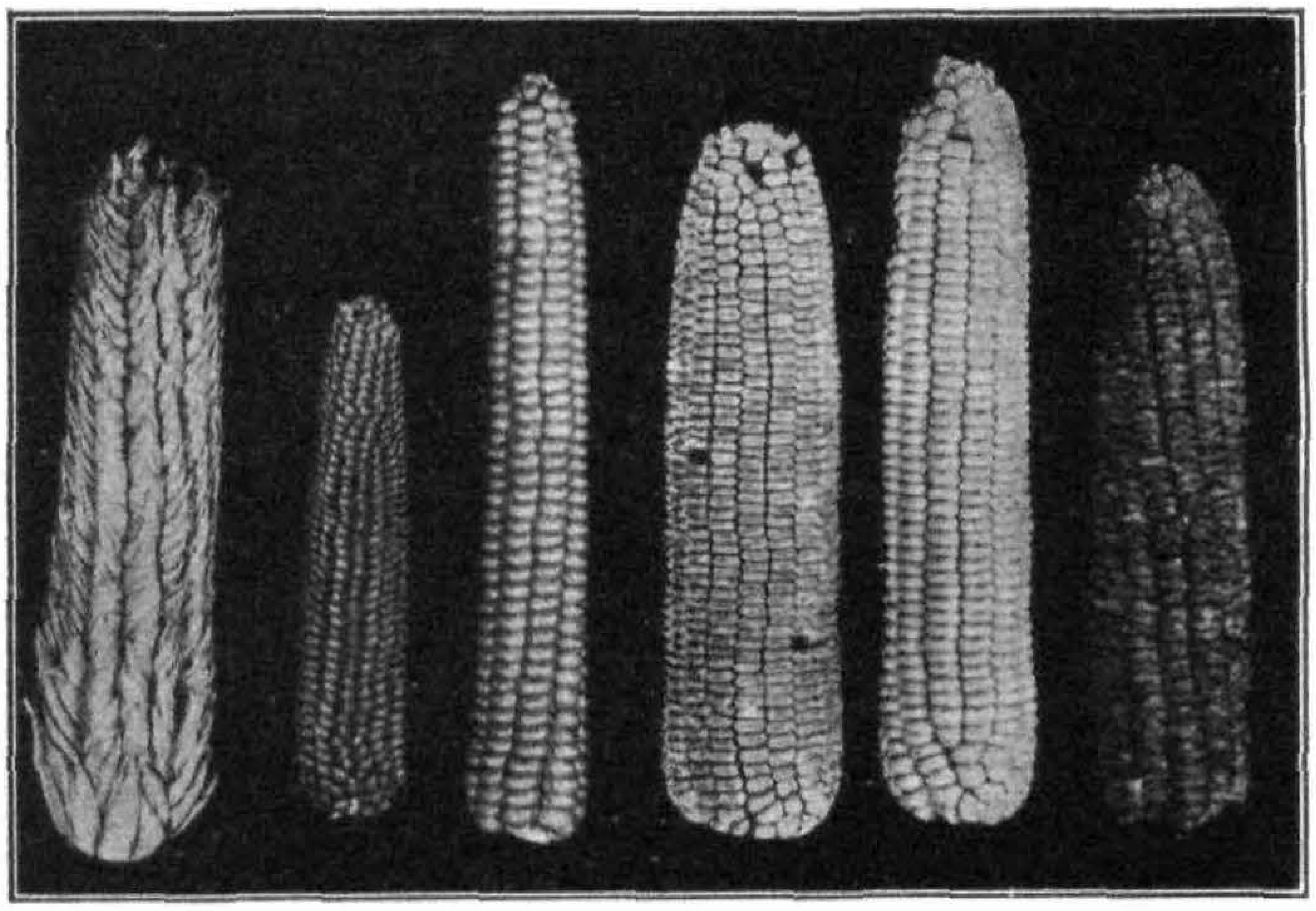


FIG. 71.—The six principal types of corn. From left to right, pod corn, pop corn, flint corn, dent corn, soft corn, and sweet corn. (*After Montgomery.*)

canina Watson, the Maiz de Coyote, is a branching plant producing many small ears (2 to 4 inches long) on lateral branches. It has been produced artificially by crossing a common maize and teosinte. It is said to grow wild in Mexico at the present time. *Zea mays japonica* is an ornamental sort with small, flinty grains. *Zea mays hirta* is a hairy, South American corn. *Zea mays curagua* is a form with serrate leaves.

The distinguishing characteristics of the seven groups above are shown in the following key:

KEY TO "SPECIES GROUPS" OF CORN

Each kernel enclosed in husks (glumes, lemma, palet); the ear is also enclosed in husks; a rare form, considered by some to be the primitive type, *Zea tunicata* (pod corn).

Each kernel naked, not enclosed in pod or husk:

- Grains with popping properties; popping is due to the turning inside out of the kernel through the explosion of the contained moisture when heat is applied; pericarp is thick and tough; excessive proportion of horny (corneous) endosperm; kernels and ears small, *Zea everta* (pop corn).
- Grains without popping properties.
  - No corneous endosperm, hence grains are soft; shaped like flint corn; no indentation; the mummy corns of Peru, Mexico, and southern United States probably belong to this group, *Zea amylacea* (soft corn).
  - Corneous endosperm present.
    - Grains more or less wrinkled or shrivelled; kernels horny and translucent in appearance.
      - Grains horny throughout, *Zea saccharata* (sweet corn).
      - Grains with upper half horny and translucent, the lower half starchy, *Zea amylea-saccharata* (starchy sweet corn).
    - Grains not wrinkled, smooth.
      - Starchy endosperm extending to top of kernel; corneous endosperm at sides; shrinkage of starchy endosperm at top of grain causes a drawing in of pericarp and hence the characteristic dent formed (Fig. 64), *Zea indentata* (dent corn).
      - Starchy endosperm enclosed by the corneous endosperm; hence there is no shrinkage of top of grain and no dent formed (Fig. 69), *Zea indurata* (flint corn).

Zea amylea-saccharata (starchy sweet corn) is a group of only botanical interest. Some seed of this was found in the San Padro Indian collection by Dr. Palmer and sent to Sturtevant in 1886. This seed was planted at Geneva, New York, but the crop failed and the seed was lost.

In *Zea saccharata*, the power to develop starch grains to maturity has been lost. The starch that is formed remains small, angular, and does not have the appearance of the typical corn starch granule. Sweet corns may be regarded

as dent, flint, and pop corns that have lost the power to mature starch normally.

FIG. 72.—Teosinte (Euchlæna mexicana). (*After Collins and Kempton in Journal of Heredity.*)

Origin of Maize.—Although maize or Indian corn has been in cultivation since prehistoric times, it is unknown in the wild state. It is generally agreed, however, that it is distinctly of American origin. The nearest known wild relative

of maize is a Mexican grass, *teosinte* (*Euchlæna mexicana*), with which it is known to hybridize (Fig. 72).

Harshberger is inclined to believe "that Indian corn is the result of a cross between teosinte and a race or variety of the plant produced by successive cultivation of the wild plant until its characters as a variety or a race have become fixed." Collins produces evidence to show that maize originated as a hybrid between teosinte and as unknown grass belonging to the tribe Andropogoneæ. He believes this grass to be much like the earless varieties of pod corn (*Zea tunicata*). Montgomery suggests that teosinte and corn had a common ancestor, which was a "large, much-branched grass, each branch being terminated by a tassel-like structure, bearing hermaphrodite flowers." His views coincide with those of East and Hayes (see page 165), and Weatherwax.

Environmental Relations.—Corn is a native of semi-tropical America. Its range of distribution has been extended widely through culture. A number of varieties will mature grain as far north as southern Canada, and as a green fodder it is raised in still colder regions, where the season is too short to mature the grain.

Flint varieties are now grown quite abundantly throughout northern Wisconsin; they are better adapted to cool climates than dent corn. In general, corn is not a big crop north of the summer isotherm of 69°F. The principal corn belt of the United States is a strip running from eastern Nebraska to western Ohio, the northern limit being southern Wisconsin and Minnesota. This is a region with warm summer days and nights. The chief limiting factor to corn growing in the northern tier of States is cool nights.

Reference to page 120 shows that the water requirement of corn stands between that of sorghum and wheat. There is a significant difference in the water requirement of the varieties of corn, indicating that some may be more drought-

resistant than others. Corn is being raised with profit on the dry lands of the West.

There is a close correlation between the yield of corn and the rainfall for June and July. The critical month is July. Smith says that the most critical ten-day period for corn, in Ohio, is from August 1 to 10, the period following blossoming, when the weather must be wet and moderately cool.

In the corn districts west of the 95th meridian, hot winds sometimes prove fatal to corn. These winds are particularly harmful during the critical periods of "tasseling" and "silking."

Corn thrives best in a well-drained, medium loam soil, such as is found in the river bottoms of the Mississippi Valley. It will grow on soils so rich in nitrogen as to cause the lodging of the small grains.

Uses of Corn.—No other cereal is put to such a variety of uses as is corn. Some economical use has been found for nearly every part of the plant. There are numerous manufactured corn products and by-products. Corn meal, both yellow and white, is one of the chief forms in which the grain is used as a food for man. Whole meal includes the embryo, endosperm and hull, while new process meal has the embryo and hull removed. Other forms in which corn as a human food is used are: hominy, green corn, canned corn, corn oil, corn flakes, pop corn, starch and glucose. The sweet corn canning industry is a large one. Corn starch from which the protein and mineral matter have been removed by treatment with dilute alkaline solutions gives a flour which is used largely in the preparation of puddings, blanc manges, etc.

Corn oil is obtained from the embryo. When freshly prepared, it is pale yellow in color. It is employed in the manufacture of soap, and paints, and when mixed with linseed oil, it has some value as a grinding oil. Corn oil is also sometimes vulcanized into a cheap grade of rubber.

Corn Starch.—About 50,000,000 bushels of corn are used annually in the United States in the manufacture of commercial starches, and products derived from them. In the manufacture of corn starch, the corn is steeped from two to four days in warm water containing about 0.2 per cent. of sulphurous acid. Steeping is instituted in large wooden vats holding about 2,000 bushels of corn. When the grains are softened sufficiently, they are lead through a Fuss mill which thoroughly breaks up the grain. The embryos are separated from the rest of the grain material, and removed to another receptacle. The disintegrated grains are freed from the embryos, mixed with water, more finely ground and then shaken through bolting-cloth sieves. Starch and gluten pass through the sieves, while the coarser materials, such as fragments of the pericarp, are caught by the sieve. The liquor containing starch and gluten is passed over tables, very slightly inclined, and as the liquid slowly flows down these tables, the starch granules settle, while the lighter particles of gluten are carried off the lower end. The starch is removed from the tables, washed, and kiln-dried.

Glucose.—The commercial "glucose" is a thick syrup—a product of the partial hydrolysis of starch. The manufacture of corn starch has been described. The "green starch" from the tables is made into a thick cream by mixing with water. This is then passed to *converters* where the starch is treated with hydrochloric acid to bring about its partial hydrolysis. The converted liquor is blown out of the converters into the *neutralizer*, where it is treated with a dilute solution of sodium carbonate, which neutralizes the acid, and precipitates the dissolved iron, and coagulates the colloidal albuminoids. The neutral liquor is then filtered, first in bag filters, and then in bone-char filters. From the first bone-char filters, there issues a *light liquor*. This is evaporated to increase its concentration, and passed on as

heavy liquor to the bone-char filter again. The liquor that results from this second filtering is boiled down in vacuum pans, whence it comes as the finished *glucose*.

Pure glucose syrup has little flavor, and but half the sweetness of cane syrup. Maize syrup is mixed with varying quantities of cane syrup and sold as a substitute for golden syrup and molasses. It is the basis of many manufactured jellies and preserved fruits.

Grape Sugar.—This is a crude sugar made from starch, in a manner very similar to that employed in the manufacture of glucose. However, hydrolysis is more complete, the process of conversion being carried to the point that no dextrin is precipitated when a sample is placed in strong alcohol. Grape sugar appears on the market as a hard, waxy solid. It finds considerable use in the manufacture of sparkling ales; and, also, as a reducing agent in indigo dyeing, and other industries.

Artificial Gums.—These are known as *dextrins* and *British gums*, and are made from starch. Starch is heated to a temperature varying from 170 to 270°C. During this process, the starch may be treated with dilute nitric acid to bring about hydrolysis, although if high temperatures are used, the addition of acid is unnecessary, as the starch itself contains enough acid and water to effect hydrolysis. Dextrins and British gums are used on envelopes and postage stamps, and also in many of the textile industries.

Stock Food.—Corn *fodder* includes the whole plant—stalks, leaves, and ears—and in this form is fed to stock. Corn *stover* is the stalks of corn from which the ears have been husked; the stalks may be fed in the bundle form or shredded. Fodder is an important silage crop. In the form of silage, it makes a highly nutritious, succulent feed throughout the winter. *Silage* is a forage prepared by fermenting green, fresh, plants in a specially constructed air-tight receptacle,

called a *silo*. The material to be ensilaged is cut into fine pieces and packed into the silo. *Forage crops* include, according to common usage, those plants which are grown for their vegetative parts and which are eaten, either in the green or dry state, by herbivorous animals. Some plants, such as sorghums, are grown for their grain and also for their herbage, that is, they are both a cereal and a forage crop. Corn is also both a cereal and a forage crop. The grass family (Gramineæ) and the pea family (Leguminosæ)

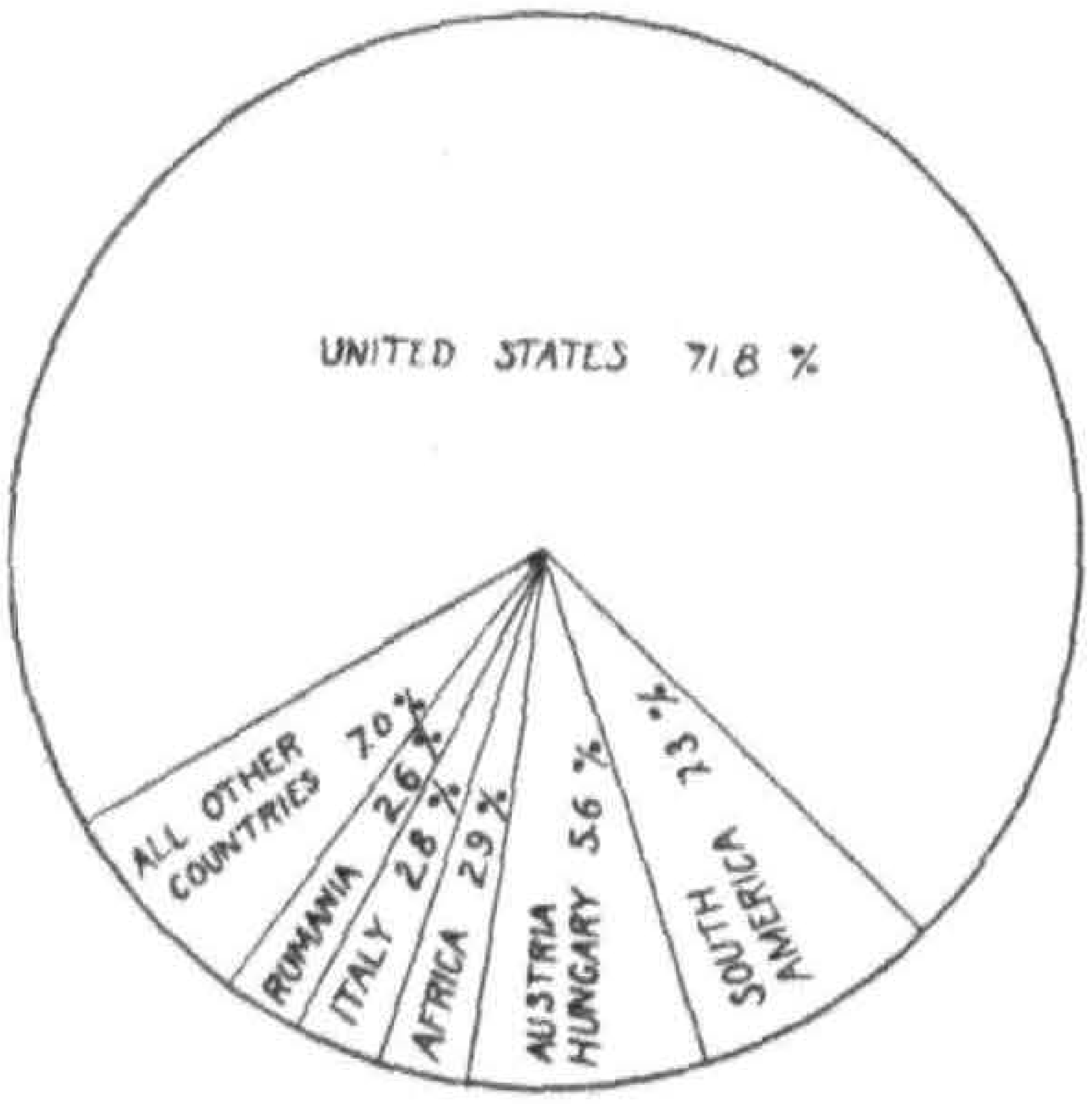


FIG. 73.—Percentage of the world's supply of corn produced in the various countries in 1914.

furnish the great majority of forage plants. Corn grain and corn bran are important stock foods.

Other Corn Products.—The pith from the stalks is made into explosives and also employed as a packing material where extreme lightness of weight is required. Corn cobs are still in demand for pipes. A fine grade of charcoal is manufactured from corn cobs. Paper is made from the stalks, and packing for mattresses from the husks. When oil is pressed from the embryos, there is left the corn cake, which may be utilized as a food for stock. Gluten meal, a by-product from starch factories, is also not infrequently fed to

stock. Corn is the most economical source of starch for alcohol manufacture in the United States. One ton of corn gives about 90 gallons of 94 per cent. alcohol.

Production of Corn.—In 1914, the United States produced 2,672,804,000 bushels of corn, which was over 70 per cent. of total production for the world. The country ranking second in its corn output was Argentine with 338,235,000 bushels. The ten leading States in the order of their production of corn in 1915 were Illinois, Iowa, Nebraska, Missouri, Indiana, Texas, Kansas, Ohio, Oklahoma, and Kentucky. The total acreage in corn in the United States that year was 108,321,000 and the total farm value of the 1915 corn crop, on the basis of the price of corn December 1, was $1,755,859,000.

References

Bohutinsky, Gustav: Entwicklungsabweichungen beim Mais. Ber. Deut. Bot. Gesell., 32: 179–188, 1914.

Bowman, M. L., and Crossley, B. W.: Corn: Growing, Judging, Breeding, Feeding, Marketing. Waterloo, Iowa, 1911.

Burtt, Davy, J.: Botanical Characters of the Maize Plant. Transvaal Agr. Jour., 7: 348–395, 1909.

Incomplete Dichogamy in Zea Mays. Jour. Bot. (London), 47: 180–182, 1909.

Maize, Its History, Cultivation, Handling, and Uses. Longmans, Green & Co., 1914.

Collins, G. N.: A New Type of Indian Corn from China. U. S. Dept. Agr. Bur. Plant Ind. Bul. 161: 1–25, 1909.

Apogamy in the Maize Plant. U. S. Nat. Mus. Contrib. Nat. Herbarium, 12: 453–455, 1909.

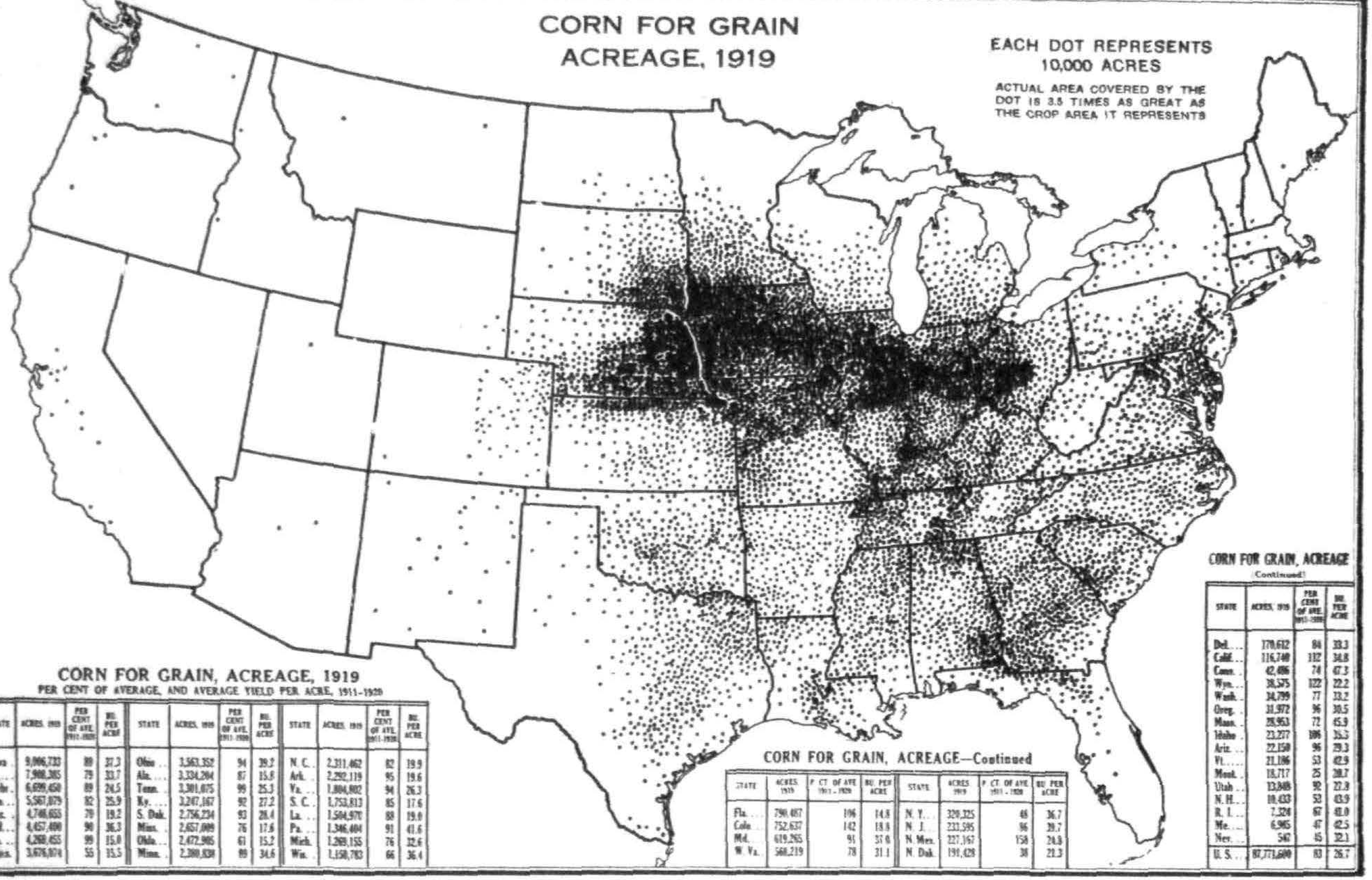
The Origin of Maize. Jour. Washington Acad. Sci., 2: 520–530, 1912.

A Variety of Maize with Silks Maturing Before the Tassels. U. S. Dept. Agr. Bur. Plant Ind. Cir. 107: 1–11, 1913.

A Drought-resisting Adaptation in Seedlings of Hopi Maize. U. S. Dept. Agr. Jour. Agr. Research, 1: 293–302, 1914.

Correns, C.: Untersuchungen über die Xenien bei Zea mays. Ber. Deut. Bot. Gesell., 17: 410–417, 1899.

Crozier, A. A.: Silk-seeking Pollen. Bot. Gaz., 13: 242, 1888.



CORN FOR GRAIN, ACREAGE, 1919

PER CENT OF AVERAGE, AND AVERAGE YIELD PER ACRE, 1911-1920

STATE	ACRES, 1919	PER CENT OF AVE. 1911-1920	BU. PER ACRE	STATE	ACRES, 1919	PER CENT OF AVE. 1911-1920	BU. PER ACRE	STATE	ACRES, 1919	PER CENT OF AVE. 1911-1920	BU. PER ACRE
Iowa	9,006,733	89	37.3	Ohio	3,563,352	94	39.2	N. C.	2,311,462	82	19.9
Ill.	7,908,385	79	33.7	Ala.	3,334,204	87	15.8	Ark.	2,292,119	95	19.6
Nebr.	6,699,450	89	24.5	Tenn.	3,301,075	99	25.3	Va.	1,884,802	94	26.3
Mo.	5,567,079	82	25.9	Ky.	3,247,167	92	27.2	S. C.	1,753,813	85	17.6
Tex.	4,748,655	79	19.2	S. Dak.	2,756,234	93	28.4	La.	1,504,970	88	19.0
Ind.	4,457,490	90	36.3	Miss.	2,657,009	76	17.6	Pa.	1,346,404	91	41.6
Ga.	4,268,455	99	15.0	Okla.	2,472,905	61	15.2	Mich.	1,269,155	76	32.6
Kans.	3,676,074	55	15.5	Minn.	2,380,839	89	34.6	Wis.	1,150,783	66	36.4

CORN FOR GRAIN, ACREAGE—Continued

STATE	ACRES 1919	P. CT. OF AVE. 1911-1920	BU. PER ACRE	STATE	ACRES 1919	P. CT. OF AVE. 1911-1920	BU. PER ACRE
Fla.	790,487	106	14.8	N. Y.	329,325	48	36.7
Colo.	752,637	142	18.8	N. J.	233,595	96	39.7
Md.	619,265	91	37.0	N. Mex.	227,167	158	24.8
W. Va.	568,219	78	31.1	N. Dak.	191,428	38	21.3

CORN FOR GRAIN, ACREAGE

(Continued)

STATE	ACRES, 1919	PER CENT OF AVE. 1911-1920	BU. PER ACRE
Del.	170,612	84	33.3
Calif.	116,740	112	34.8
Conn.	42,406	74	47.3
Wyo.	38,575	122	22.2
Wash.	34,799	77	33.2
Oreg.	31,972	96	30.5
Mass.	28,963	72	45.9
Idaho	23,277	106	35.3
Ariz.	22,150	96	29.3
Vt.	21,186	53	42.9
Mont.	18,717	25	20.7
Utah	13,848	92	22.8
N. H.	10,433	52	43.9
R. I.	7,324	67	41.0
Me.	6,965	47	42.5
Nev.	547	45	32.1
U. S.	87,771,600	83	26.7

EAST, E. M.: Inheritance of Color in the Aleurone Cells of Maize. Amer. Nat., 46: 363–365, 1912.
A Chronicle of the Tribe of Corn. Pop. Sci. Mo., 82: 225–236, 1913.
EAST, E. M., and HAYES, H. K.: Inheritance in Maize. Conn. Agr. Exp. Sta. Bull. 167: 1–142, 1911.
FISHER, M. L.: Report of Work in Corn Pollination, I. Proc. Ind. Acad. Sci., 1908.
Report of Work in Corn Pollination, II. Proc. Ind. Acad. Sci., 1910.
Report of Work in Corn Pollination, III. Proc. Ind. Acad. Sci., 1911.
GAGER, C. S.: An Occurrence of Glands in the Embryo of Zea Mays. Bull Torrey Bot. Club, 34: 125–137, 1907.
GERNERT, W. B.: Methods in the Artificial Pollination of Corn. Am. Breeders' Assn., 7: 353–367, 1911.
A New Subspecies of Zea Mays. Am. Nat., 47: 616–622, 1912.
GUIGNARD, L.: La double fécondation dans le mais. Jour. Bot. (Paris), 15: 37–50, 1901.
HARSHBERGER, J. W.: Maize: A Botanical and Economic Study. Contrib. Bot. Lab. Univ. Pa., 1: 75–202, 1893.
Fertile Crosses of Teosinite and Maize. Gard. and Forest, 9: 522–523, 1896.
A Study of the Fertile Hybrids Produced by Crossing Teosinte and Maize. Contrib. Bot. Lab. Pa., 2, 1901.
HOPKINS, C. G., SMITH, L. H., and EAST, E. M.: The Structure of the Corn Kernel and the Composition of its Different Parts. Ill. Agr. Exp. Sta. Bull. 87: 77–112, 1903.
HUS, H., and MURDOCK, A. W.: Inheritance of Fasciation in Zea Mays. Plant World, 14: 88–96 1911.
KELLERMAN, W. A., and SWINGLE, W. T.: Preliminary Study of the Receptivity of Corn Silk. 2d Ann. Rept. Kans. Agr. Exp. Sta., 353–355, 1890.
Bibliography of Cross-fertilization of Varieties of Corn. 2d Ann. Rept. Kans. Agr. Exp. Sta., 346–353, 1890.
Experiments in Cross-fertilization of Corn. 2d Ann. Rept. Kans. Agr. Exp. Sta., 288–334, 1890.
Experiments in Crossing Varieties of Corn. 2d Ann. Rept. Kans. Agr. Exp. Sta., 2: 288–334, 1890.
KEMPTON, JAMES H.: Floral Abnormalities in Maize. U. S. Dept. Agr. Bur. Plant Ind. Bull. 278: 1–16, 1913.
MILLER, EDWIN C.: Comparative Study of the Root Systems and Leaf Areas of Corn and Sorgums. Jour. Agr. Res. 6: 311–332, 1916.
Development of the Pistillate Spikelet and Fertilization in Zea Mays L. Journ. Agr. Res., 18: 255–267, 1919.
MONTGOMERY, E. G.: What is an Ear of Corn? Pop. Sci. Mo., 68: 55–62, 1906.

Perfect Flowers in Maize. Pop. Sci. Mo., 79: 346–349, 1911.
The Corn Crops. The Macmillan Co., New York, 1913.
PEIRSON, HENRY: Abnormal Development in Maize. Jour. Bot. (London), 49: 347–348, 1911.
POINDEXTER, C. C.: The Development of the Spikelet and Grain of Corn. Ohio Nat., 6, 1903.
SARGENT, ETHEL, and ROBERTSON, AGNES: The Anatomy of the Scutellum in Zea Mays. Ann. Bot., 19: 115–123, 1905.
SHOESMITH, V. M.: The Study of Corn. Kans. Agr. Exp. Sta. Bull. 139: 223–249, 1906.
The Study of Corn. Orange Judd Co., 1910.
STEWART, ALBAN: The Pistillate Spikelet in Zea Mays. Science, n.s. 42: 694, 1915.
STURTEVANT, E. L.: Notes on Maize. Torrey Bot. Bull. 21: 319–343, 1894.
Varieties of Corn. U. S. Dept. Agr. Office Expt. Stats. Bull. 57: 1–103, 1899.
WEATHERWAX, PAUL: Morphology of the Flowers of Zea Mays. Bull. Torrey Bot. Club, 43: 127–144, 1916.
The Development of the Spikelets of Zea Mays. Bull. Torrey Bot. Club, 44: 483–496, 1917.
The Evolution of Maize. Bull. Torrey Bot. Club, 45: 309–342, 1918.
The Story of the Maize Plant. The University of Chicago Press, 1923.
WEBBER, H. J.: Xenia, or the Immediate Effect of Pollen in Maize. U. S. Dept. Agr. Div. Veg. Path. and Veg. Phys., 22: 1–44, 1900.

CHAPTER XV

ANDROPOGON SORGHUM (Sorghums[1])

Habit of Plant, and Roots.—All sorghums are annual plants with a well developed root system. The roots are generally finer and more fibrous than those of maize. The root crowns and laterals show a vigorous growth. Comparative studies show that certain sorghums possess a root system as extensive as that of corn and that they have "twice as many secondary roots as corn at any stage of its growth." This condition, coupled with the smaller leaf surface of sorghums would appear to account for the comparatively great drought resistance of the sorghums. The roots of all sorghums are tough and wiry.

Stems and Leaves.—The culms vary in height from 3 to 15 feet. They are solid; the internodes and leaf sheaths are about equal in length. Sorghums produce both "suckers" and side branches from buds placed in the axils of the leaves. As many as 10 or 15 suckers may be produced from one plant; they differ from the main stalk in that they are less tall, and mature later. Side branches do not appear until the main stem is headed out. The heads on these branches are smaller and less productive than those on the main stalk, and they mature much later.

The leaves are very similar to those of corn.

Inflorescence.—This is a panicle, which, with a few exceptions (*e.g.*, broom corn), is rather compact. It is called the "head." These heads may vary (Fig. 77) a great deal in

[1] The term "sorghum" includes all the groups known in the United States as milo, kowliang, shallu, durra, broom corn, and kafir.

shape and color. The axis of the inflorescence is rather angular. The side branches are in apparent whorls, one above the other. The spikelets usually occur in pairs (Fig. 74), although toward the tip of the inflorescence they may occur in threes.

Spikelets and Flowers.—It was stated that the spikelets usually occur in pairs. One is sessile, the other pedicelled. The sessile one is broad, thick, and fertile; the pedicelled

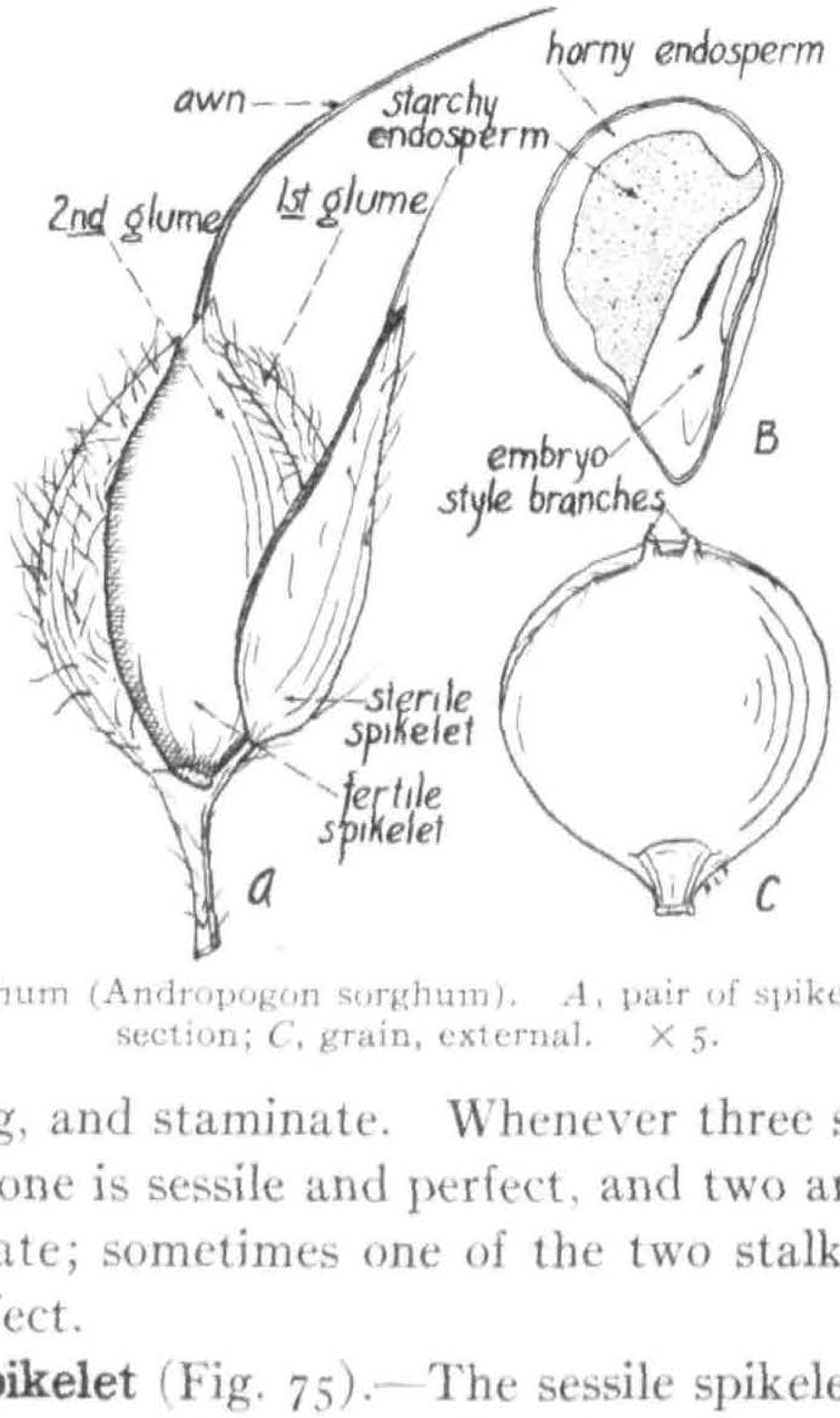


Fig. 74.—Sorghum (Andropogon sorghum). A, pair of spikelets; B, grain in section; C, grain, external. × 5.

narrow, long, and staminate. Whenever three spikelets are in a group, one is sessile and perfect, and two are pedicelled and staminate; sometimes one of the two stalked spikelets may be perfect.

Fertile Spikelet (Fig. 75).—The sessile spikelet has thick, leathery glumes of about equal length. The outer one partially wraps about the inner. The latter is narrower and more gradually tapering at the tip. Within the two glumes of this sessile spikelet, are two flowers; the lower sterile, the

upper with both stamens and pistil. The so-called "third glume" of some descriptions is the lemma of the lower, sterile flower. Moreover, it is the only remnant of this flower. It encloses the parts of the fertile flower. The lemma of the fertile flower is broad, hairy, and two-cleft at the tip; there arises in the cleft, as a rule, a long awn which projects from

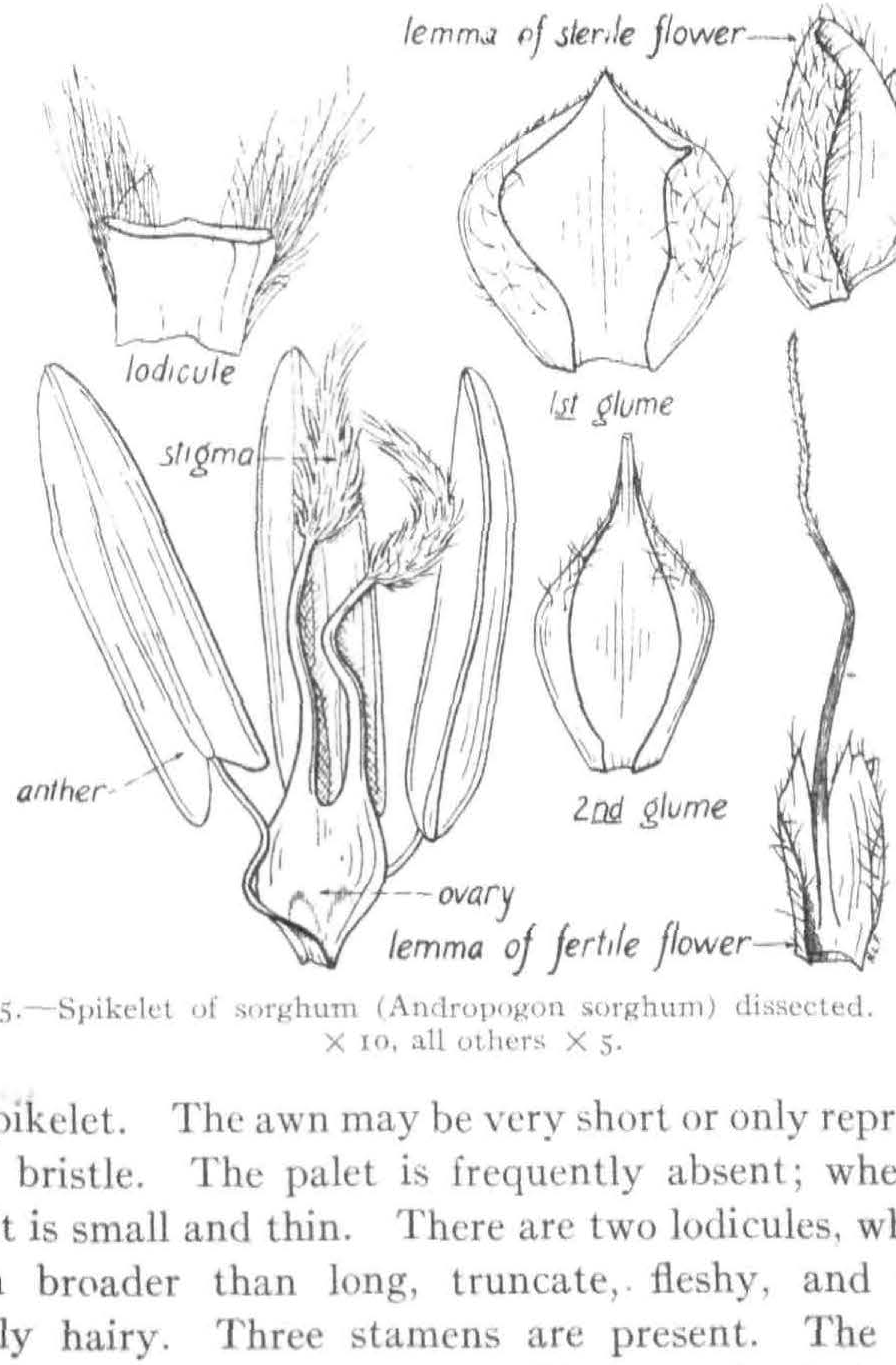


FIG. 75.—Spikelet of sorghum (Andropogon sorghum) dissected. Lodicule × 10, all others × 5.

the spikelet. The awn may be very short or only represented by a bristle. The palet is frequently absent; when present, it is small and thin. There are two lodicules, which are much broader than long, truncate, fleshy, and usually thickly hairy. Three stamens are present. The sessile, ovate ovary does not bear a tuft of hairs at the tip, such as is found in wheat, oats, rye and barley. The two styles are

thread-like and bare for the lower two-thirds of their length, and then spread out into bushy stigmas.

Staminate Spikelet.—The stalked spikelet is narrower, and more pointed than the fertile one. It is two-flowered. It is subtended by two leathery glumes. Immediately within this pair is the lemma of the sterile flower of the spikelet. Then comes the lemma of the staminate flower; it may be short-awned or awnless; the palet of this flower is absent. The lodicules and stamens resemble those of the fertile spikelet. There is no pistil.

Opening of Flowers and Pollination.—Flowers do not begin to open on the inflorescence until the latter is entirely out of the leaf sheath. The first flowers to open are those near the tip of the head. Blooming proceeds from the tip downward. As a rule, flowers at the tip of an inflorescence have shed their pollen, and closed, when the lower flowers of the head are just beginning to bloom. Flowers on branches belonging to one whorl are usually in about the same stage of blooming. In nearly all cases, the sessile spikelet of a pair is the first to open. The stalked spikelets may sometimes fail to protrude their stamens. Most of the flowers open in the early morning; there is but a very slight amount of blooming during the day. The stigmas may protrude to a slight extent first (Fig. 76). They are followed by the anthers. When the flower starts to open, the whole process takes place within from ten to fifteen minutes. The spreading of the glumes, and the emergence of anthers and styles may be so rapid in some instances as to be seen with the hand lens. The stamens extend their full length, as a rule, and the anthers swing on long filaments. In some cases, however, the anthers never fully project from between the glumes, but shed their pollen, and dry up, half or one-fourth caught by the glumes. When the anthers are partly out, the stigmas are fully protruded. No sooner are the anthers visible than they begin

to dehisce by two narrow slits at the tip only. The stigmas and pollen-shedding anthers may be in contact at time of opening, and since the stigma is receptive at this time,

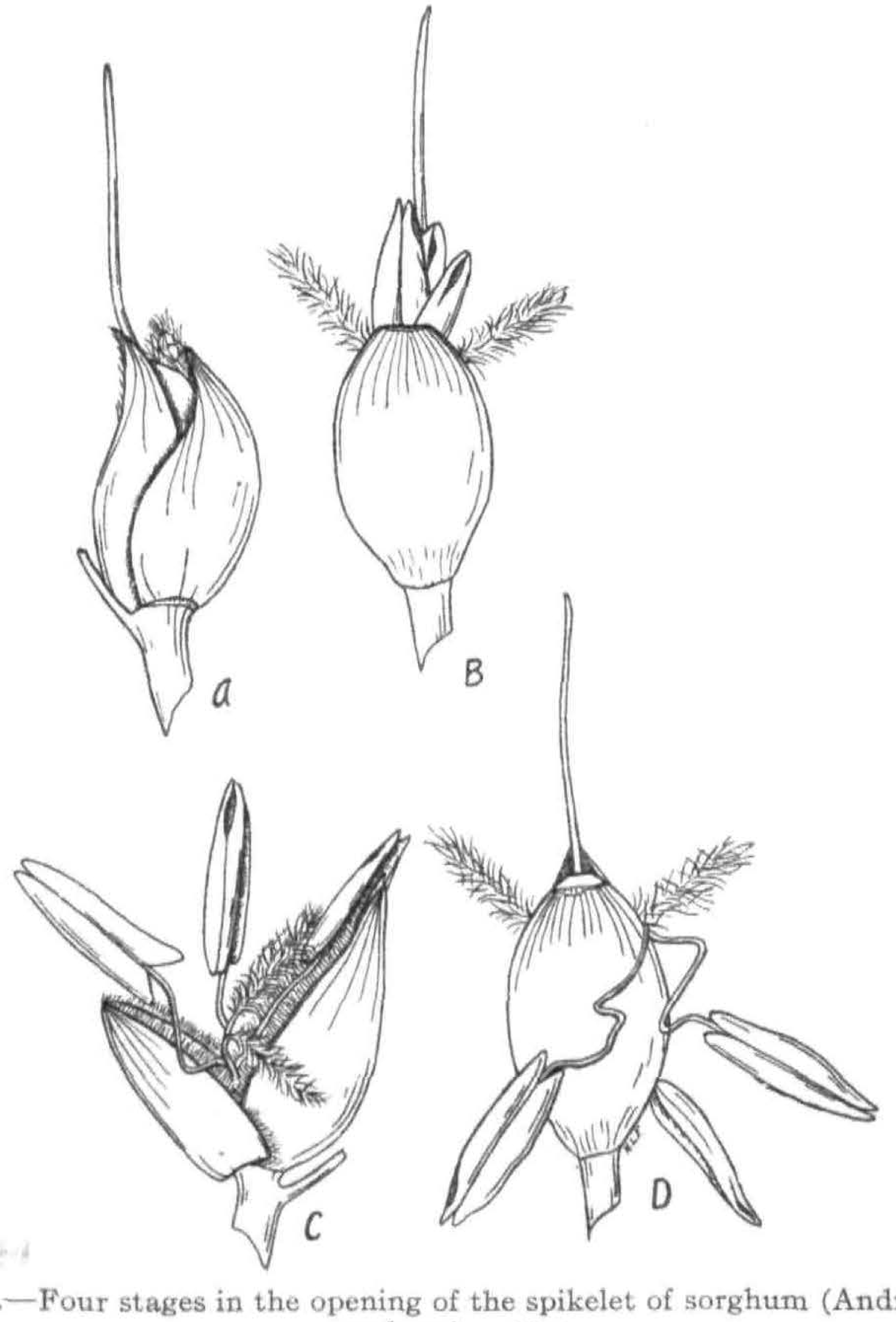


FIG. 76.—Four stages in the opening of the spikelet of sorghum (Andropogon sorghum). × 5.

some self-pollination must take place. Pollination between flowers of the same plant is very common. The upper flowers are shedding pollen in abundance, as the receptive stigmas of lower flowers are opening. And, in the light breeze of

the morning, the head is moved enough to shake pollen out. Cross-pollination is also very common. Individual flowers do not, as a rule, remain open longer than the evening of the day they open. The brown and withered stamens and stigmas commonly protrude from between the closed glumes.

The different types of sorghum cross readily.

Fruit.—The mature grain may be entirely or in part enclosed by the "glumes." It is oval, a little longer than broad, smooth, and tipped with the remains of two style branches. The position of the embryo is seen at the base of the grain on one of the flat surfaces. The point of attachment—an oval, brown area—is found at the base of the grain on the other flat surface.

The seed is flattened in the durras, pyriform in some of the sorgos, and globular in kafir, kowliang, and shallu.

In some types of sorghum, the pericarp bears starch. The aleurone layer consists of one row of small cells. The starchy endosperm is mealy within and more or less horny without.

Germination of Seed.—As with other cereals, in the germination of sorghum the radicle is the first to appear, and is followed by the plumule. However, as distinguished from the other common cereals, there is but one temporary root developed in sorghum which has a few branch laterals. The first whorl of permanent roots begins to develop within three or four days following the emergence of the plumule, and comes from a node which arises about one-half inch below soil surface.

Varieties.—The sorghums are divided into two main divisions: (1) saccharine or sweet sorghums, and (2) non-saccharine sorghums. Saccharine sorghums are tall, leafy, and have an abundance of sweet juice, and a light crop of seed. The chief varieties are Amber, Orange, and Sumac. Non-saccharine sorghums are more stocky, as a rule, contain less juice, and have a heavy crop of seed. Non-saccharine sor-

ghums are divided into three groups; (1) *kafir group*, including those with erect, long cylindrical heads full of obovate seeds (kafirs, white milo, etc.); (2) *durra group*, including those with thick, compact, ovate, pendant inflorescences, and large, flattened seeds (yellow milo, durra, feterita); and (3) *broom corn group*, in which the heads are loose and spreading. Frequently the heads are on recurved stems, called "goose necks."

KEY TO THE PRINCIPAL GROUPS OF SORGHUM[1]

Pith juicy.
- Juice abundant and very sweet.
  - Internodes elongated; sheaths scarcely overlapping; leaves 12 to 15 (except in Amber varieties); spikelets elliptic-oval to obovate, 2.5 to 3.5 millimeters wide; seeds reddish brown, *Sorgo*.
- Juice scanty, slightly sweet to subacid.
  - Internodes short; sheaths strongly overlapping; leaves 12 to 15; peduncles erect; panicles cylindrical; spikelets obovate, 3 to 4 millimeters wide; lemmas awnless, *Kafir*.
  - Internodes medium; sheaths scarcely overlapping; leaves 8 to 11; peduncles mostly inclined, often recurved; panicles ovate; spikelets broadly obovate, 4.5 to 6 millimeters wide; lemmas awned, *Milo*.

Pith dry.
- Panicle lax, 2.5 to 7 decimeters long; peduncles erect; spikelets elliptic-oval or obovate, 2.5 to 3.5 millimeters wide; lemmas awned.
  - Panicle 4 to 7 decimeters long; rachis less than one-fifth as long as the panicle.
    - Panicle umbelliform, the branches greatly elongated, the tips drooping; seeds reddish, included, *Broom Corn*.
  - Panicle 2.5 to 4 decimeters long; rachis more than two-thirds as long as the panicle.
    - Panicle conical, the branches strongly drooping; glumes at maturity spreading and involute, seeds white or somewhat buff, *Shallu*.
    - Panicle oval or obovate, the branches spreading; glumes at maturity appressed, not involute; seeds white, brown, or reddish, *Kowliang*.
- Panicle compact, 1 to 2.5 decimeters long; peduncles erect or recurved; rachis more than two-thirds as long as the panicle.
  - Spikelets elliptic-oval or obovate, 2.5 to 3.5 millimeters wide; lemmas awned, *Kowliang*.

[1] Taken from Ball.

Spikelets broadly obovate, 4.5 to 6 millimeters wide.
  Glumes gray or greenish, not wrinkled; densely pubescent; lemmas awned or awnless; seeds strongly flattened, *Durra*.
  Glumes deep brown or black, transversely wrinkled; thinly pubescent; lemmas awned; seeds slightly flattened, *Milo*.

Origin of Sorghums.—There is still some doubt as to the actual prototypes of the cultivated sorghums. *Andropogon halepensis* (Johnson grass), has been regarded by some as the wild form from which our cultivated sorghums have been derived, but more recent investigations point to *A. sorghum* and *A. halepensis* as two distinct botanical species. Whereas, the latter is characterized by the presence of rootstocks, in *A. sorghum*, rootstocks are absent.

Environmental Relations.—Sorghums are of tropical origin, and are at home in regions with warm, sunshiny summers. The plant will undergo high temperatures. It is sensitive to low temperatures, and consequently cannot be planted as early in the season as the other small cereals.

The sorghums are either able to resist or to escape drought. For this reason they have become one of the principal crops on the non-irrigated lands of the West. Their resistance to drought is due largely to their low water requirement, along with their ability to roll the leaves with approaching dry periods, and thus reduce the water-losing surface, and also to their ability to remain alive during a period of drought and quickly resume growth when moisture is available. In this last respect the sorghums differ from corn, for corn is unable to remain in a dormant state for a very long time. The sorghums are not as easily affected by hot winds as corn. This is an important characteristic adapting them to the semi-arid regions.

Sorghums will grow on a variety of soils. They are somewhat more resistant to alkali salts than the other grain crops.

Uses of Sorghums.—The saccharine or sweet sorghums are grown for syrup and for forage. The juice is extracted

Above this sterile flower, is a perfect one. The lemma of this is parchment-like, broad, and seven-nerved; it encloses the three-nerved palet. The two lodicules are fleshy, smooth, and somewhat broader than long. Stamens are three in number. There are two plumose style branches.

Pollination.—This millet is quite regularly cross-pollinated; however, self-pollination is not excluded.

Mature Grain.—The kernel is firmly surrounded by the indurated, shining lemma and palet. The whole grain measures about 3 millimeters in length and 2 millimeters in width. The kernel itself is broadly oval, smooth, white, and does not possess a groove or furrow as does wheat. The position of the embryo is indicated by a shallow broad marking about one-half the length of the kernel. The wall of the kernel is thin. There is one row of small, flat aleurone cells surrounding the starchy endosperm.

Varieties.—Koernicke recognizes three main types of broom-corn millet. These are as follows:

1. *Panicum miliaceum effusum.*—Panicle broad, the branches spreading to all sides.

2. *Panicum miliaceum contractum.*—Panicle less spreading than preceding, one-sided.

3. *Panicum miliaceum compactum.*—Panicle compact, thick, and erect.

Origin.—The native home of *Panicum miliaceum* is not known. The plant has been cultivated in Europe and Asia from the earliest times.

CHÆTOCHLOA ITALICA (Foxtail Millets)

Stem.—The plants are erect and from 2 to 5 feet tall. The culms are cylindrical; they may branch near the base, but such branches seldom produce flowers and fruit.

Leaf.—The leaf sheaths are open, and smooth or hairy. The ligule is short, thick, and fimbriated; auricles are

2. *Chætochloa italica moharium.*—Heads short, thick, erect, or drooping but very slightly. This group also has two subdivisions: short-bristle and long-bristle varieties. Here belongs Hungarian millet.

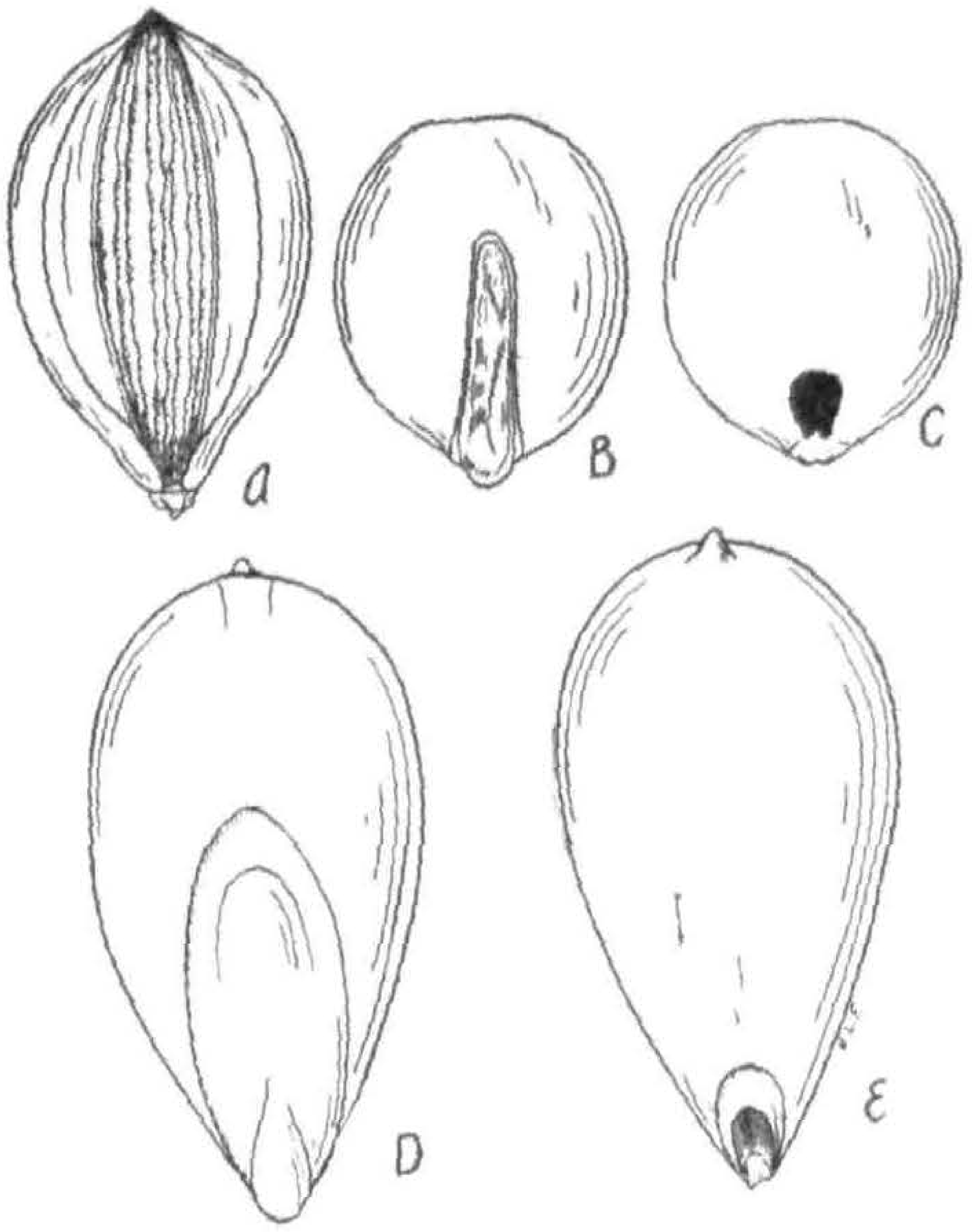


FIG. 88.—*A*, grain of foxtail millet (Chætochloa italica) with lemma and palet attached; *B*, grain of same, embryo side with "hull" removed; *C*, grain of same, side opposite the embryo; *D* and *E*, grains of pearl millet (Pennisetum spicatum). × 10.

KEY TO PRINCIPAL TYPES OF FOXTAIL MILLETS (CHÆTOCHLOA ITALICA)[1]

Heads small, uniform, compact, seeds yellowish to black with usually a large percentage very dark; beards brown or purple, *Hungarian Millet.*

Heads large, more or less open; seeds more or less bunched.

- Heads long, slender, very open, lax, drooping; seed groups very distinct, *Aino Millet.*
- Heads shorter and plumper, bushy, erect or slightly drooping; seed groups indistinct.
  - Seeds yellow.
    - Profusely bearded; medium large heads.

[1] After Frear.

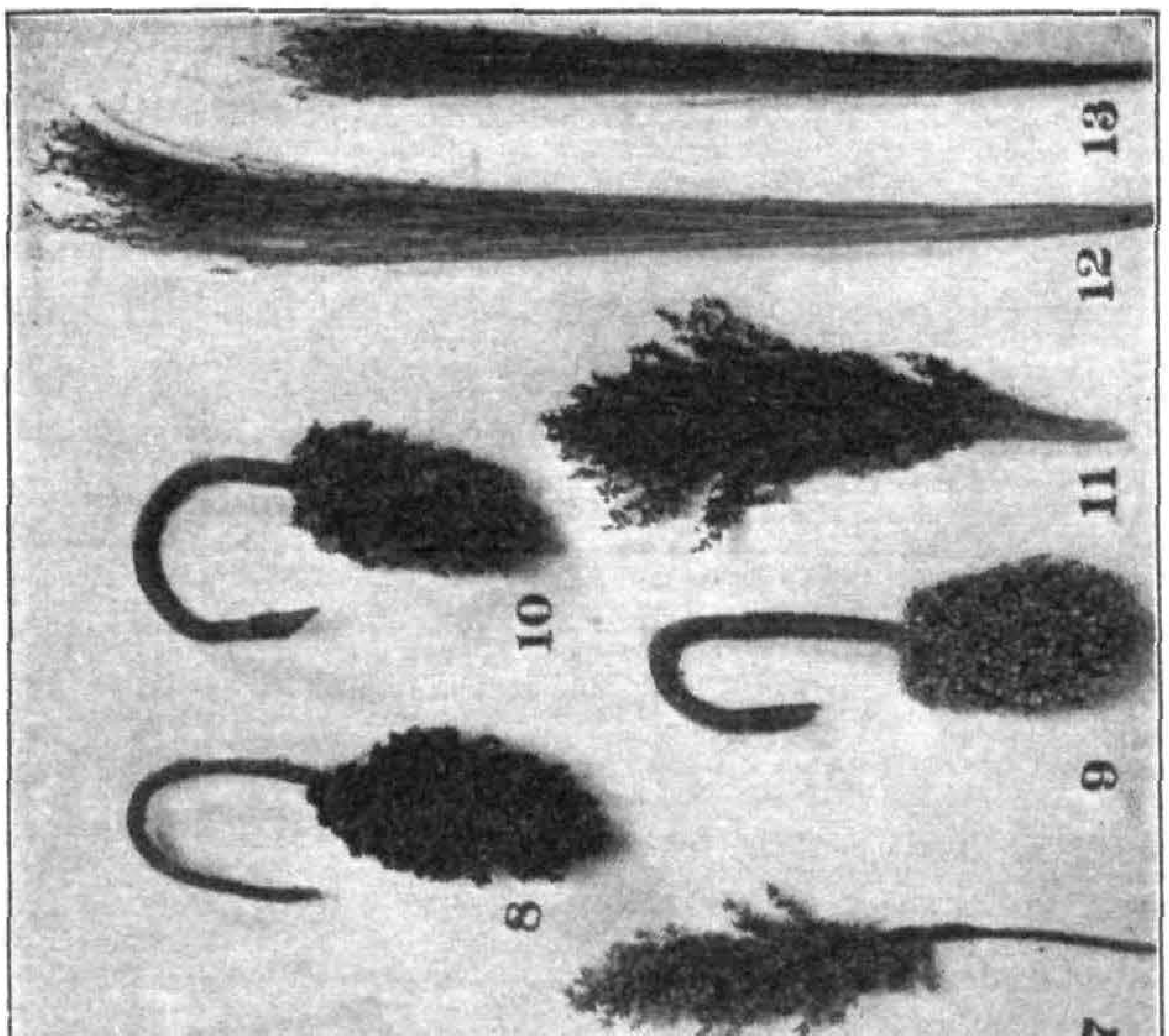


FIG. 77.—The principal types of sorghum (Andropogon sorghum). 1, Amber; 2, orange; 3, sumac; 4, red kafir; 5, pink kafir; 6, blackhull kafir; 7, shallu; 8, milo; 9, white durra; 10, brown durra; 11, brown kowliang; 12, standard broom-corn; 13, dwarf broom-corn. (*After Montgomery.*)

from the canes. Sorghum for syrup is cut when the seed is in the late milk or dough stage. The main stalk only is used when a high grade of syrup is desired. This necessitates "stripping" the stems of leaves, head and suckers. Sorghum grown for syrup is usually planted somewhat thinner than that for forage and silage. The leading State in sorghum-syrup production is Tennessee. The non-saccharine sorghums are grown chiefly for their grain, but also for forage. The Chinese and Manchus put the grain sorghums to a great variety of uses. For example, a fermented drink is made from the seed, the heads are used for fuel and brooms, the leaves for fodder and for mats, the stalks for the construction of baskets, fences, building material, laths, playthings, posts, thatchings, wind breaks, and window shades, and even the roots and stubble are used as fuel. The broom-corn groups of sorghums are grown for their grain, and certain varieties with long rachi are made into brooms. For this purpose the heads are used. Brooms are made from two different groups of broom corn: *tall-growing* or Standard, and *dwarf*. Fully two-thirds of the total broom-corn crop of the United States is dwarf broom corn. It produces a fiber that is finer than that of the tall-growing sort; and, too the head is not so firmly attached to the upper node. This latter character permits the "brush" (inflorescence) to be harvested by pulling. After threshing the grain from the heads, they are cured in sheds or out of doors in ricks. They are then graded and baled, and either stored or shipped directly to the broom factory. The "straws" of a broom are the rachises of the sorghum inflorescence. Oklahoma, Kansas, and Texas, in the order named, are the leading broom-corn States.

References

BALL, CARLETON R.: Saccharine Sorghums for Forage. U. S. Dept. Agr. Farmers' Bull. 246: 7–18, 1906.

Three Much Misrepresented Sorghums. U. S. Dept. Agr. Bur. Plant Ind. Cir. 50: 1–14, 1910.

The History and Distribution of Sorghum. U. S. Dept. Agr. Bur. Plant Ind. Bull. 175: 1–63, 1910.

Better Grain-sorghum Crops. U. S. Dept. Agr. Farmers' Bull. 448: 1–36, 1911.

The Importance and Improvement of the Grain Sorghums. U. S. Dept. Agr. Bur. Plant Ind. Bull. 203: 1–45, 1911.

The Grain Sorghums, Immigrant Crops that Have Made Good. U. S. Dept. Agr. Yearbook, 1913: 221–238.

HACKEL, E.: Die kultivirten Sorghum—Formen und ihre Abstammung. Jahrb. (Engler), 7: 115–126, 1885.

PIPER, C. V.: The Prototype of the Cultivated Sorghums. Jour. Am. Soc. Agron., 7: 109–117, 1915.

HARTLEY, CHARLES P.: Broom Corn. U. S. Dept. Agr. Farmers' Bull. 174: 1–30, 1903.

ROTHGEB, B. E.: Dwarf Broom Corns. U. S. Dept. Agr. Farmers' Bull. 768: 1–16, 1916.

WARBURTON, C. W.: The Non-saccharine Sorghums. U. S. Dept. Agr. Farmers' Bull. 288: 1–28, 1907.

CHAPTER XVI

ORYZA SATIVA (Rice)

Roots, Stems, Leaves.—Common cultivated rice is an *annual* plant, which grows best under swampy or very moist conditions. There are upland varieties produced with irrigation, but the lowland type is the sort almost entirely grown in the United States. The seedling has one seed root. The *root system* is fibrous; the first, second, and third nodes give rise to adventitious roots. The first whorl of permanent roots is close to 1/2 inch above the lower end of the culm. It is more shallow in very moist ground than in dry soil. The plant tillers freely, sending up usually four or five hollow *stems* to a height of 2 to 6 feet. The *leaf sheaths* are open, and the blades are from 8 to 12 inches long and 3/4 to 1 inch wide. The ligule is long, acute or obtuse, and easily splits into two parts. It is much shorter and more rounded on the upper leaves than on the lower. The auricle is white or green, cartilaginous or membranous, and hairy.

Inflorescence and Spikelet.—The inflorescence is a panicle (Fig. 78). Its branches are either single or in pairs. The spikelet (Fig. 79) is compressed laterally. It is one-flowered. There are two small scale-like or bristle-like glumes, underneath each of which is a very minute, rudimentary glume. The lemma is compressed, parchment-like and five-nerved. The palet is similar to the lemma in size and texture, but is only three-nerved. Both may be awned or awnless. The broadly oval lodicules are small, thick, and fleshy. Rice differs markedly from the other common cereals in having six well-developed and functioning stamens. The

ovary is somewhat longer than broad, smooth, and bears two

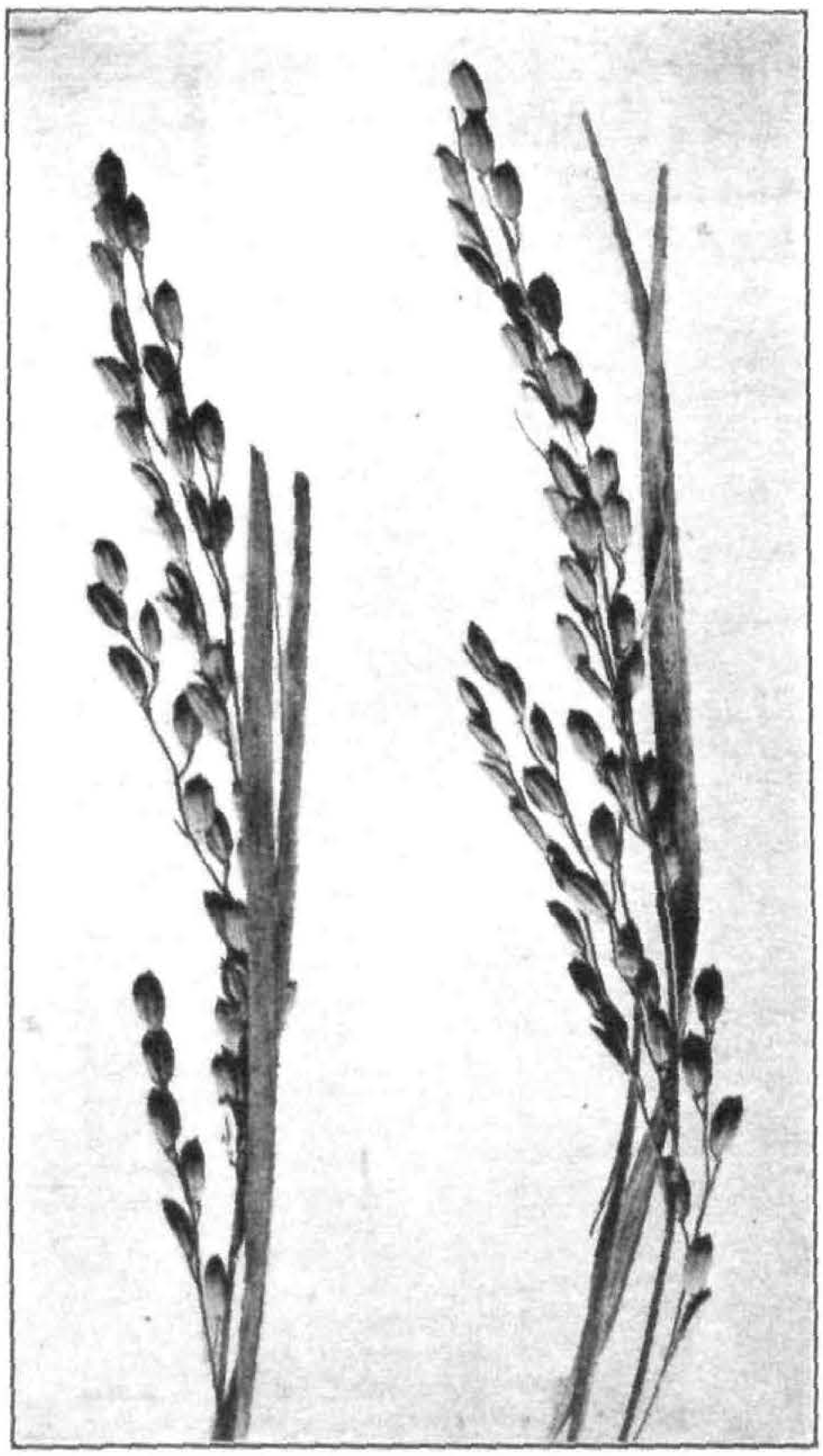


FIG. 78.—Panicle of rice (Oryza sativa).

styles, and sometimes a short, rudimentary third one. These three are sometimes grown together at the base.

Pollination and Fertilization.—Rice is normally self-pollinated. The flowers at the tip of the inflorescence are the first to open. Flower opening continues throughout the day. The stamens are the first flower parts to appear. After they are extended full length, the lemma and palet open wider,

and the stigmas protrude. Usually the stigmas draw back between the palet and lemma after pollination, although they may remain outside. The anthers are open and the stigma is covered with pollen at the time of opening of the flower. Although self-fertilization is the normal process, cross-fertilization is not altogether precluded.

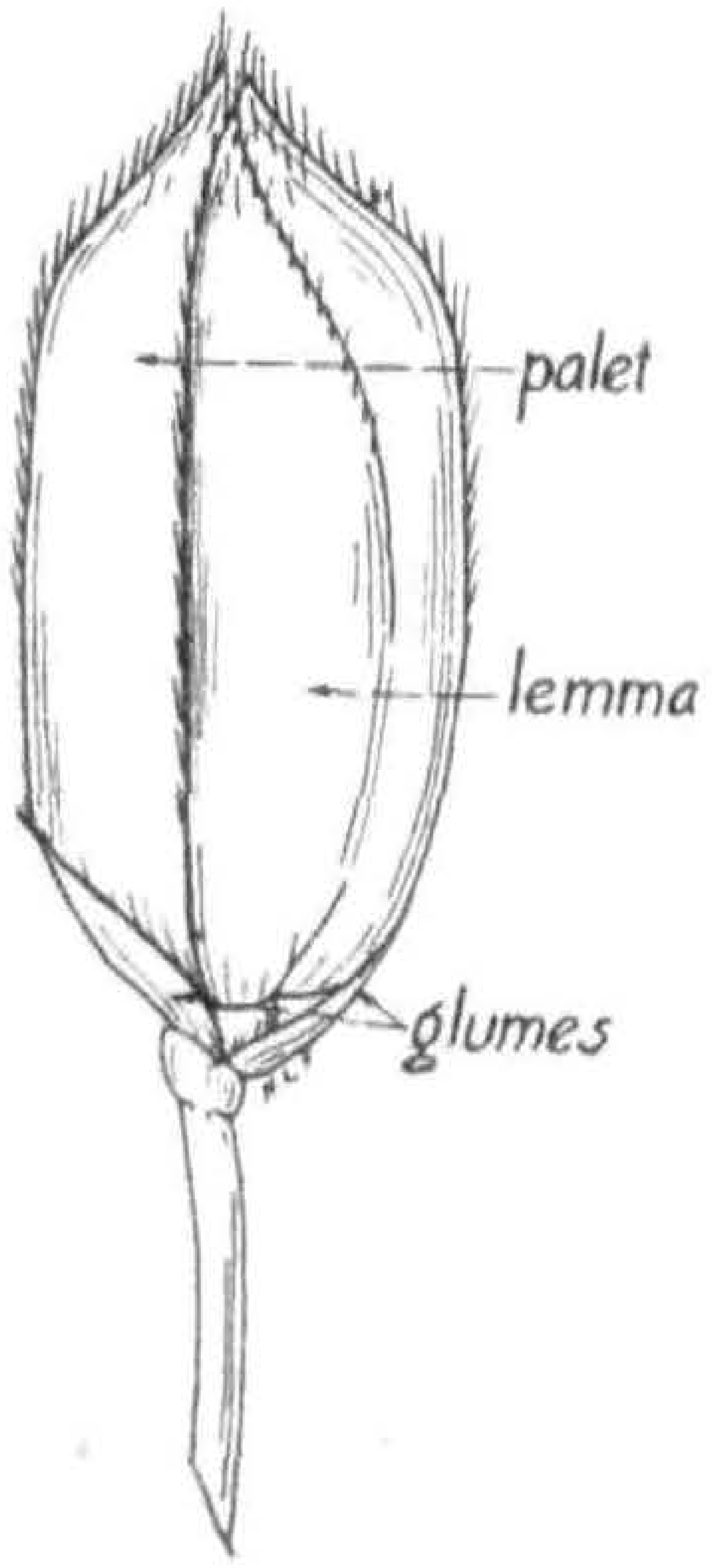


FIG. 79.—Spikelet of rice (Oryza sativa).

Grain.—The rice grain (caryopsis) is surrounded by the lemma and palet, or palet alone. These two structures form the "hull." Rice enclosed in the hull is known as "paddy." Rice from which the hull has been removed is "cleaned rice." The rice grain (Fig. 80) is smooth, longer than broad, and elliptical in cross-section. There are two longitudinal parallel ridges on each of the flat surfaces. The grain of common rice is shiny and transparent. This appearance is due to the glassy endosperm. Occasionally there are grains that appear dull; in such, the endosperm is starchy on the outside and horny within. Grains with dull areas here and there are not uncommon. An interesting rice is *Oryza glutinosa*, the grains of which always appear dull. A cut surface of this rice is described as paraffin-like in appearance. The starch grains behave quite differently from those of common rice. They color yellow-brown with iodine instead of violet. When it is cooked, there is formed a mass the particles of which stick closely together; the single grains do not remain separate. There are rices with grains pale green in color, reddish-brown, dark brown, and white with red or dark stripes.

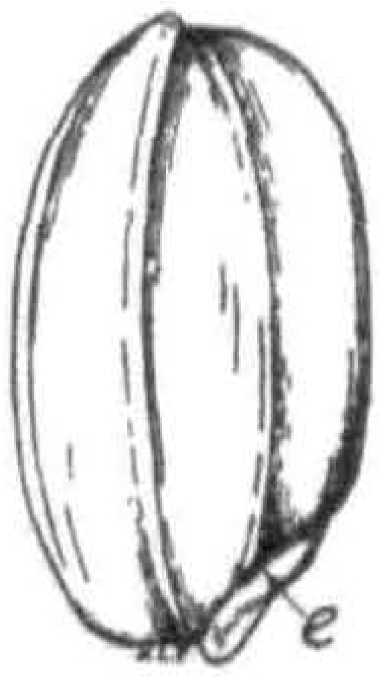


FIG. 80.—Kernel of rice (Oryza sativa). *e*, embryo. × 5.

In cross-section of the rice grain, the layers are very similar to those in wheat. There is the pericarp of several layers, the testa, the nucellus (perisperm), and the aleurone layer, usually of one row of cells. The embryo is about one-third the length of the fruit. During the milling process, the lemma and palet, the embryo, pericarp, testa, nucellus, and in many cases all or a portion of the aleurone layer are removed. This "scouring process," in the case of Honduras and Japan rices, removes about 10 per cent. of the weight of the grain, and a considerable quantity of ash, fat, crude fiber, protein, and pentosans. The color of red rice is located in the seed coat, or throughout the endosperm.

Milling of Rice.—The threshed rice from the field is called "paddy rice." The grains are enclosed by the glumes, lemma, and palet, which together constitute the "hull." The hulls are removed by passing the grains between revolving millstones, set apart about two-thirds the length of a rice kernel. The hulls are then removed by a fanning device, and this process followed by the separation of the rough (unhulled) from the clean rice in the "paddy machine." The next process removes a part of the bran layer (pericarp, testa and nucellus) and most of the embryo. After a separation of the powdery bran from the cleaned rice, the grains are then led into the "pearling cone" where they are scoured. This is followed by a thorough polishing between pieces of pigskin. The grains then receive a coating of glucose and talc, and are ready to be graded and packed for the market.

Varieties.—Carleton gives the following provisional arrangement of wild and cultivated rices:

1. Oryza granulata (wild rice).
2. Oryza officinalis (wild rice).
3. Oryza sativa (cultivated rice).
   (*a*) utilissima.
      1. communis (large-kerneled rice).

2. minuta (small-kerneled rice).

(*b*) glutinosa (glutinous rice).

American varieties are comparatively few in number. Three main types are grown: Honduras, Carolina and Japan. The hulls of Honduras and Japan rice are yellowish-brown, those of Carolina rice mostly a golden yellow. Lowland types of rice form, almost exclusively, the sorts grown in this country. Japan rice has smaller grains, a thinner hull, and tillers more than the other types in the United States. Honduras and Carolina belong to the *communis* group, and Japan to the *minuta* group. It should be stated here that there is an exceedingly large number of rice varieties.

Distribution and Closely Related Species.—There is a great number of *Oryza* species found growing wild in tropical regions of both hemispheres. The native home of *O. sativa* is the warm parts of Asia and Africa. Cultivated rice probably originated in eastern Asia. It is of interest to note that based upon the number of human beings which use rice as a staple food, it is the most important food plant in the world. It is said to have been introduced into China 3000 years before Christ.

In this country, there are two quite common, native plants termed "rice." These are, Canada rice (*Zizania aquatica*), and wild rice (*Zizania miliacea*). Both are tall aquatic grasses belonging to the same tribe (Oryzeæ) as cultivated rice. Both species of *Zizania* differ from *Oryza* in having monœcious spikelets.

Uses of Rice.—Rice is a food for more human beings than is any other grain. It is the principal food of the densely populated regions of China, India, and the neighboring islands. The consumption of rice per capita in the United States is steadily increasing. Orientals do not polish their rice, while all the rice that comes on the market in this country has had the hull removed, and has been polished. Rice

hulls and rice flour or polish, removed in the milling process, are used as stock food. Rice straw is also used as a food for stock, and in the manufacture of paper, straw hats, straw board, etc. In Japan, a drink called "sake," similar to beer, is made from rice.

Environmental Relations.—Rice has a climatic range similar to that of cotton; it is seldom raised north of that region

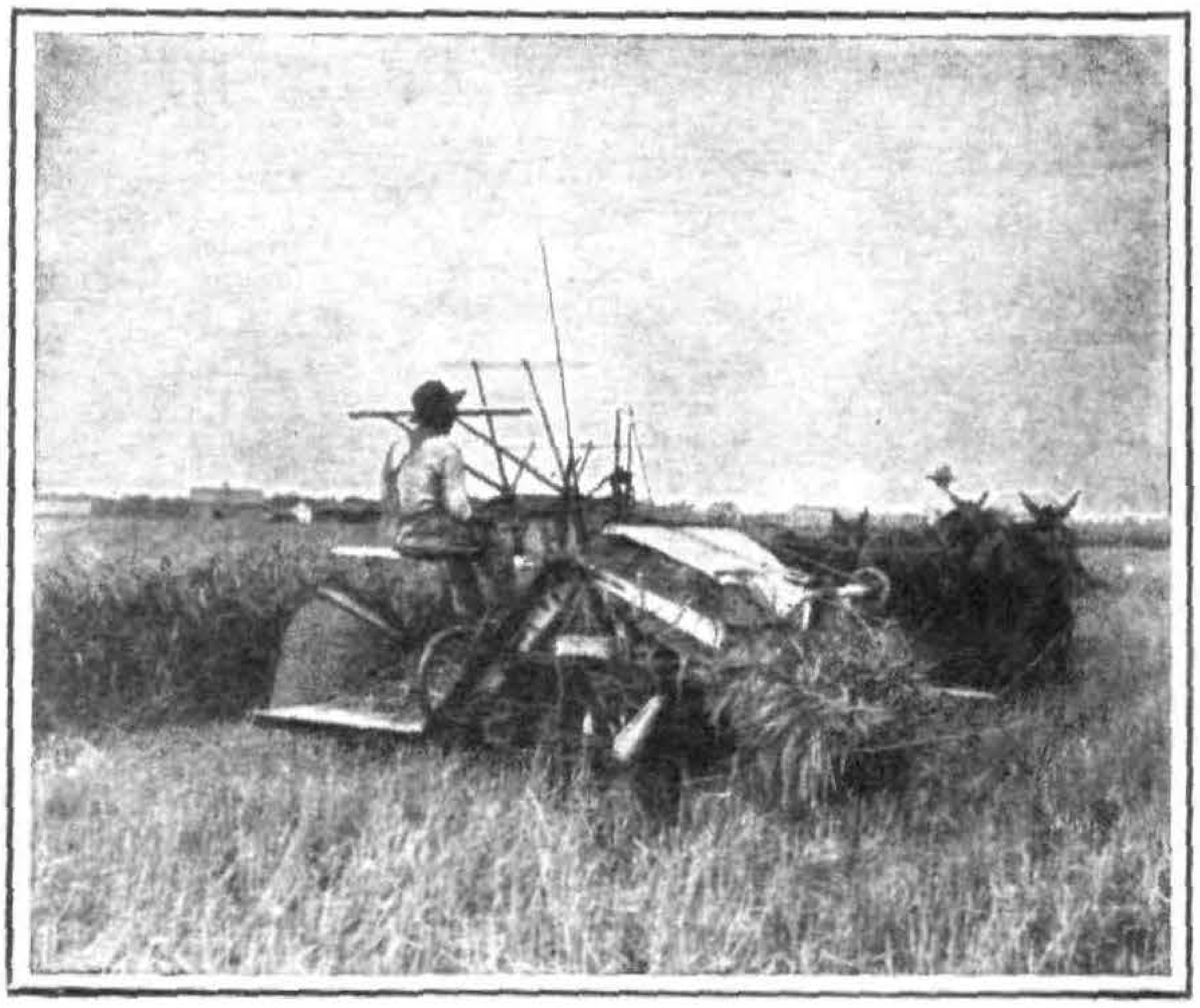


FIG. 81.—Harvesting rice in Arkansas. *(From Essentials of Geography, Second Book. Copyright 1916, by Albert Perry Brigham and Charles T. McFarlane. American Book Company, Publishers.)*

in which the average summer (June, July, August) temperature is lower than 77°F. It reaches its best development in moist regions. Certain sorts of upland rice are planted, cultivated and harvested like oats. But, most of the rice is raised on low delta or alluvial lands that will permit of inundation. In lowland rice culture, flooding of the field is usually resorted to in order to hasten germination; after the plants have attained a height of several inches, from 3 to 6 inches of water are turned on to the field and kept there continuously for twenty, thirty, or more, days, de-

pending upon the region. The water is renewed occasionally to prevent it from becoming stagnant. It is drained off just prior to the ripening of the grain.

FIG. 82.—Rice-producing regions. (*From Essentials of Geography, Second Book. Copyright, 1916, by Albert Perry Brigham and Charles T. McFarlane. American Book Company, Publishers.*)

The Production of Rice.—British India produced 62,-638,912,000 pounds of rice in 1914. During the same period, Japan raised 17,826,240,000 pounds, Java and Madura (1913) 7,951,049,000 pounds, Korea 3,678,878,000 pounds,

the Philippine Islands 1,403,516,000 pounds, Italy 741,263,-000 pounds, and the United States 656,917,000 pounds.

There are four commercial rice-growing districts in the United States: (1) The Carolina district, (2) the Texas-Louisiana district, (3) The Arkansas district, and (4) the California district. The heaviest producer is the Texas-Louisiana district. Louisiana produced 16,011,667 bushels of rice in 1919, or about one-half of the total product for the entire United States. Texas ranked second with 5,306,369 bushels, Arkansas third with 6,797,126 bushels, and California fourth with 6,926,313 bushels.

References

AKEMINE, M.: On the Flowers and Flowering of O. sativa. Agric. Gaz. Nôgyô-Sekai, 1910–11.

GRAHAM, R. J. D.: Preliminary Note on the Classification of Rice in the Central Provinces. Mem. Dept. Agr. in India, Bot. ser. 6, No. 7: 209–230, 1913.

HECTOR, P. G.: Notes on Pollination and Cross-fertilization in the Common Rice Plant, Oryza sativa, Mem. Dept. Agr. in India, Bot. ser. VI, 1: 1–10, 1913.

KIKKAWA, S.: On the Classification of Cultivated Rice. Imp. Univ. Tokyo, Coll. Agr. Bull. III, No. 2, 11–108, 1912.

CHAPTER XVII

MILLET

The term millet does not refer to a definite botanical group (species, genus, or tribe) of plants. Originally it applied to certain species of grasses belonging to the genera *Chætochloa* (*Setaria*), *Panicum* and *Echinochloa*, which are still spoken of as the "true millets."

Agriculturally speaking, the word "millet" embraces a number of annual cereal and forage grasses which have comparatively small seeds, abundant foliage, and a fibrous root system. They are raised in Europe and the United States for forage purposes and in a number of Asiatic and African countries for human food as well.

Most of these millets belong to the four genera *Chætochloa*, *Echinochloa*, *Panicum*, and *Pennisetum*, of the tribe Paniceæ. Ragi or finger millet (*Eleusine coracana*) belongs to the tribe Chlorideæ. It is grown in India to quite an extent as a cereal but has never attained favor in the United States.

KEY TO PRINCIPAL ECONOMIC TYPES (SPECIES) OF MILLET AND SOME CLOSELY RELATED COMMON WEED GRASSES[1]

Inflorescence paniculate; no involucre below the individual spikelets.
- Inflorescence a raceme of short spikes; empty glumes awned or awn-pointed, *Echinochloa* (Barnyard millets and wild barnyard grass).
  - Awns long; spikelets white. *E. crusgalli* (common barnyard grass).
    - Awns short; spikelets brown, *E. frumentacea* (Japanese barnyard millet).
- Inflorescence a drooping panicle; empty glumes not awned, *Panicum miliaceum* (proso or broom-corn millet).

Inflorescence spicate; involucre of bristles below each spikelet.

[1] After Frear.

Grain enclosed in lemma and palet (the hull) at maturity; spike loose, *Chætochloa* (foxtail millet and foxtail grass).

Panicle usually 1 centimeter thick or less; bristles commonly green; spikelets about 2 millimeters long, *C. viridis* (green foxtail).

Panicle usually 1 to 3 centimeters thick; bristles usually purple; spikelets, 2.5 to 3 millimeters long, *C. italica* (foxtail millets).

Grain globose, forcing open the hull as it matures, and falling free when threshed; spike dense, *Pennisetum glaucum* (pearl millet).

PENNISETUM GLAUCUM (Pearl Millet)

Stem.—The plants are erect, and from 3 to 8 feet tall. The culms are cylindrical and pithy; the upper internodes are smooth, the upper nodes either smooth or short-hairy.

Leaf.—The leaf sheaths are open and hairy; the ligule is short and fimbriated; the leaf blade is lanceolate, long-pointed, and long-hairy especially on the upper side.

Inflorescence.—This is a close cylindrical spike (Fig. 83), 6 to 14 inches long and ¾ to 1 inch thick. The main axis is stiff and thick-hairy. The side branches are hairy, 7 to 8 millimeters long, and bear each one to three (commonly two) spikelets, which are surrounded by a cluster of bristles. These bristles fall with the spikelets at maturity.

Spikelet and Flower.—The lower glume is short, broader than long, and truncate; the inner glume is longer, about one-half the length of the spikelet, oval, and three- to four-nerved. Each spikelet has two flowers, the lower staminate, the upper perfect. The lemma of the lower staminate flower is oval, and three- to four-nerved; the palet is small, sometimes entirely lacking, the stamens three in number, and lodicules absent. The staminate flower in the spikelet often has both palet and stamens lacking, and in some instances the spikelet has but one flower, the staminate one being entirely lacking. In some few instances, spikelets contain two perfect flowers. The lemma of the fertile flower is oval pointed, and five- to six-nerved; the palet is oval, rounded

above, pointed, and thin-membranous; lodicules are absent; there are three stamens; the ovary is obovate, smooth and with two style branches.

Pollination.—Pearl millet is regularly cross-pollinated. The flowers near the middle of the inflorescence are the first

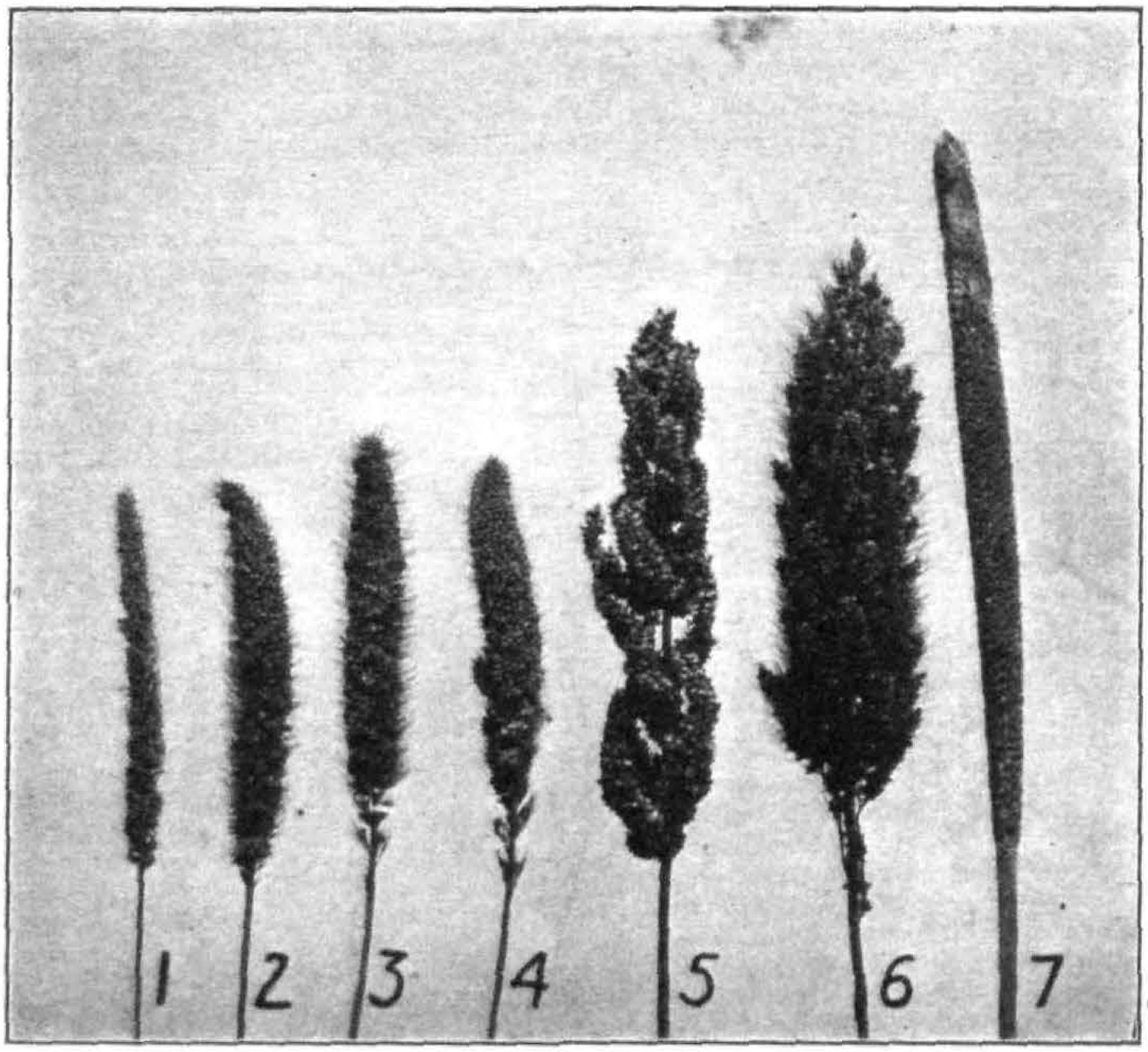


FIG. 83.—Millets. 1, Common; 2, Hungarian; 3, Siberian; 4, Golden Wonder; 5, Japanese Barnyard; 6, German; 7, Pearl.

to open. The stigmas of perfect flowers first appear between the closed glumes, then the stamens, which are in turn followed by the appearance of staminate flowers.

Mature Grain.—The kernel is 3 to 4 millimeters long, reaching the length of the glumes, obovate, somewhat flattened on the sides, and smooth. One layer of aleurone cells is present. The kernel is easily separated, as a rule, from the lemma and palet.

Varieties.—There is considerable variation in length and thickness of the inflorescence, color of inflorescence, and color of grain. No varietal classification has been made. Pearl millet is sometimes sold under the name of "*Pencilaria*" (Penicillaria) or Mand's Wonder Forage Plant. There are many common names for Pearl millet, some of which are cattail millet, African millet, Indian millet, Egyptian millet, horse millet, and Japan millet.

Origin.—The wild form from which pearl millet has come is unknown. It is probable that tropical Africa is its native home.

PANICUM MILIACEUM (Proso, Hog or Broom-corn Millet)

Stem.—The plants are erect, sometimes decumbent at the base, and often reach a height of 3 to 3½ feet. Branches frequently arise from the basal nodes, and they may bear inflorescences. The culms are cylindrical, and rough-hairy or smooth below the nodes.

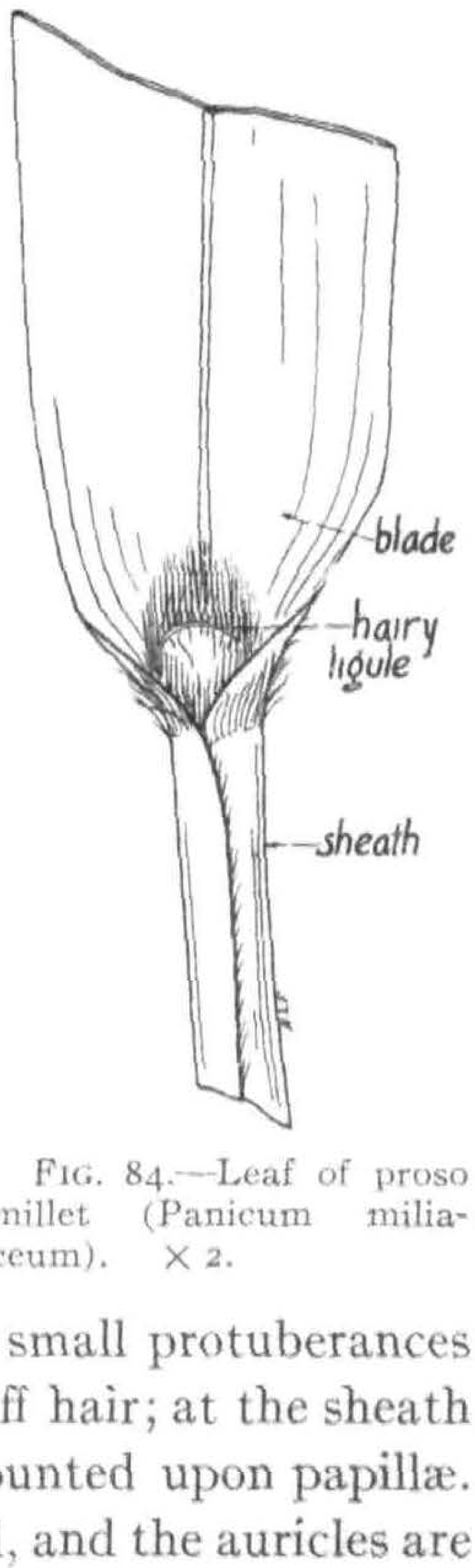


FIG. 84.—Leaf of proso millet (Panicum miliaceum). × 2.

Leaf (Fig. 84).—The leaf sheaths are open. They are covered with very small protuberances (papillæ) from each of which arises a stiff hair; at the sheath nodes the hairs are shorter and not mounted upon papillæ. The ligule is short, thick, and fimbriated, and the auricles are lacking. The leaf blade is linear lanceolate, and hairy, especially upon the upper surface.

Inflorescence.—This is a rather dense panicle (Fig. 85), 4 to 10 inches long; the erect or ascending branches are somewhat angled and rough with short hairs that point forwards.

In some varieties, the branches of the panicle spread to all sides, in others they are more or less compressed and one-sided, while in a few varieties, the panicle is much compressed, thick, and erect.

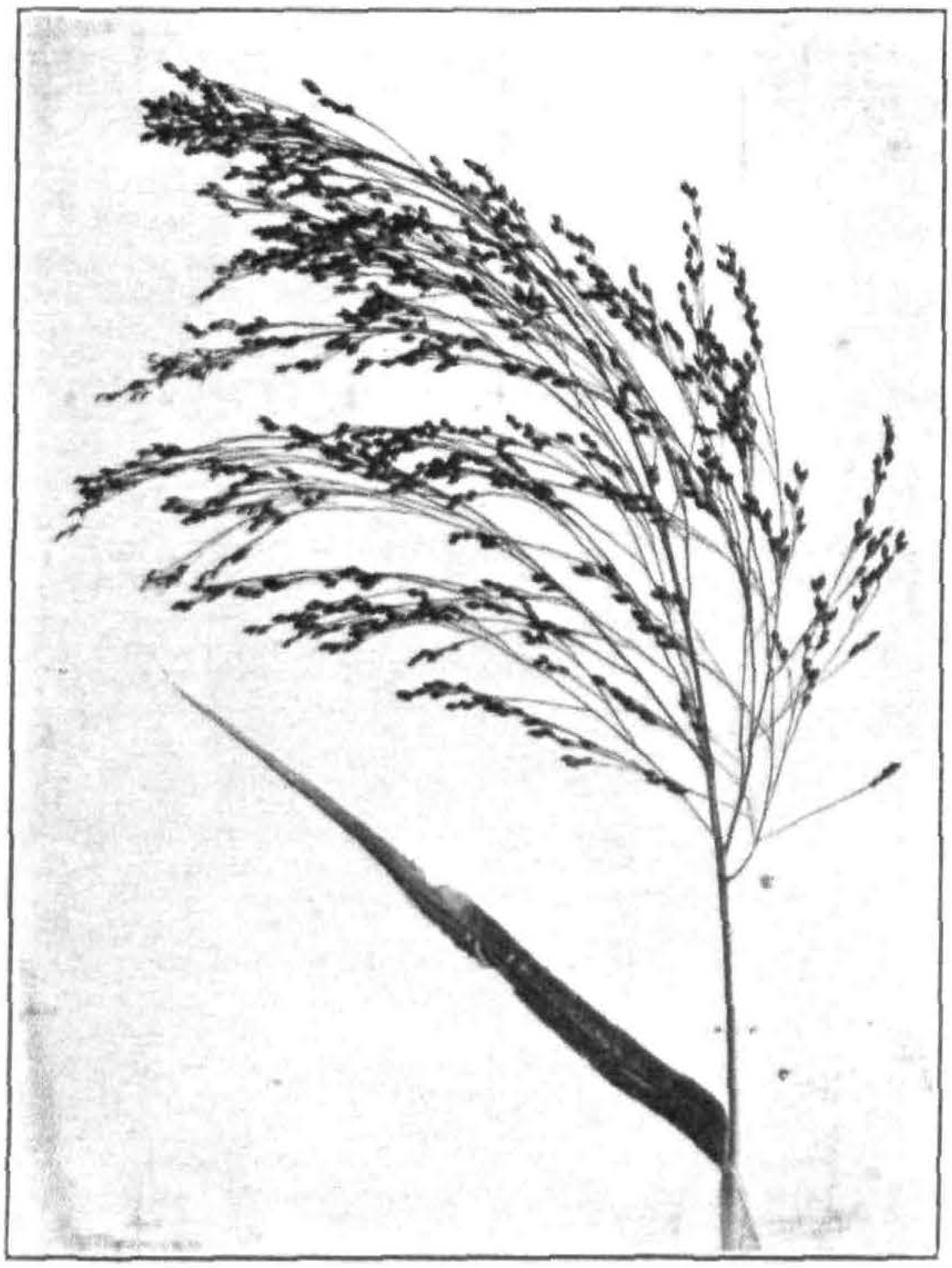


FIG. 85.—Inflorescence of proso millet (Panicum miliaceum).

Spikelet and Flower.—The spikelets are oval in shape and 4½ to 5 mm. long. The lowermost glume is broad, pointed, five- to seven-nerved, and about one-half the length of the spikelet; the second glume is the length of the spikelet and bears 13 nerves. Within the second (longer) glume is the lemma of a sterile flower; this lemma is slightly shorter than the glume surrounding it, and encloses a very small palet.

Heads large, seeds small, seed groups more distinct, *German Millet.*
Heads small, seeds large, seed groups less distinct, *Common Millet.*
Sparingly bearded; heads very large, *Golden Wonder Millet.*
Seeds red or pink, *Siberian Millet.*

Origin of Foxtail Millet.—The stem form of the foxtail millets is *Chætochloa viridis*, the green foxtail. It differs from the cultivated forms in that its fruit falls from the inflorescence when mature. *Chætochloa viridis* is a native of the Old World. It is now found in waste places in North America from Texas to Quebec.

ECHINOCHLOA CRUS-GALLI (Barnyard Grass or Barnyard Millet)

Habit, Stems, Leaves.—This grass is an annual, 2 to 4 feet tall; the culms often branch at the base. The leaves are ½ to 2 feet long, ¼ to 1 inch wide, and have smooth, glabrous sheaths and smooth or scabrous blades.

Inflorescence, Spikelet, Flowers, and Fruit.—The inflorescence is a panicle made up of from five to fifteen sessile, erect or ascending branches; the lower branches may be spreading or reflexed. The spikelets are ovate, green or purple, and densely crowded in two to four rows on one side of the rachis. Each spikelet has two flowers: a lower staminate, and an upper perfect. Within the two empty glumes is the lemma of the staminate flower; then follow the lemma and palet of the perfect flower, both of which are hard and parchment-like in texture. The lemma of the staminate flower is awned, that of the perfect flower abruptly pointed. There are three stamens, and two plumose stigmas. The kernel is firmly surrounded by the hardened lemma and palet.

Distribution.—Barnyard grass is a native of Europe. It is now widely distributed as a weed in cultivated soil and in waste places.

ECHINOCHLOA FRUMENTACEA (Japanese Barnyard Millet)

In general characters, Japanese barnyard millet corresponds very closely to common barnyard millet, except that in the main, it has a more nearly erect habit, more turgid seeds, is awnless, or has very short awns, and is brown or purplish in color. It is known as Sanwa millet in India, and "billion-dollar grass" in the United States. It probably originated from common barnyard millet (*E. crusgalli*).

Environmental Relations.—The millets require environmental conditions similar to those favoring sorghums. They are sensitive to cold, and hence must be planted after all danger from frost is over. The water requirement of millets, as a group, is less than that of sorghums. Hence they are among our most drought-resistant crops, and on this account, have been cultivated extensively on the Great Plains, from Kansas to Dakota.

Uses of Millets.—The millets are grown as a hay crop, for pasturage purposes, and for the seeds, which are most commonly fed to poultry. Millet is a quick-growing crop, and is ready to cut for hay in from six to ten weeks after seeding. The foxtail millets are more valuable for hay than the proso group. The latter is most frequently grown for the grain.

References

BALL, CARLETON, R.: Pearl millet (Pennisetum spicatum). U. S. Dept. Agr. Farmers' Bull. 168: 1–16, 1903.

CHAPTER XVIII

PHLEUM PRATENSE (Timothy)

Description.—Common timothy is a perennial grass, from 1½ to 5 feet high. Bulbs form in the lower leaf axils, a single seedling sometimes having from eight to twenty. These bulbs develop in the fall of the year, live through the winter, and send up new shoots the following season. When shoots are covered with soil, or when the plants with growing culms are covered with soil, certain of the shoots may become underground rooting stems. Thus we see that the plant reproduces vegetatively as well as by seeds. In cultivation the plant shows marked variation in stem, leaf, and inflorescence characters, in earliness, duration of bloom, longevity, vigor, stooling power, disease resistance and yield of hay and seed. The *leaves* are flat, and three to eight per stem; the upper sheaths are long, usually exceeding the internodes, and slightly inflated; the ligule is rounded. The *inflorescence* is cylindrical and spicate; although it is often called a spike, it is in reality a contracted panicle. The *spikelets* are one-flowered. Each spikelet is subtended by two membranous, compressed glumes which are ciliate on the margins (Fig. 89), truncate at the tip and awned; the lemma is much shorter and broader than the glumes, thin, truncate, and finely toothed at the apex; the palet is narrow and thin. Stamens are three in number. There are two distinct styles with plumose stigmas. The whole process of blooming and dehiscence of anthers takes place in about one and one-half hours. In blooming, the anthers are the first to emerge, but the anthers of any flower do not shed their pollen until the

stigmas of that flower have been exposed for some time. It has been observed that the number of days the individual heads remain in bloom varies from six to sixteen. The upper third of the head blooms first. The time of blooming is from about midnight until about sunrise. The egg-shaped *grain* is enclosed by the lemma and palet. Self-fertilization usually occurs in timothy, although cross-fertilization may also take place.

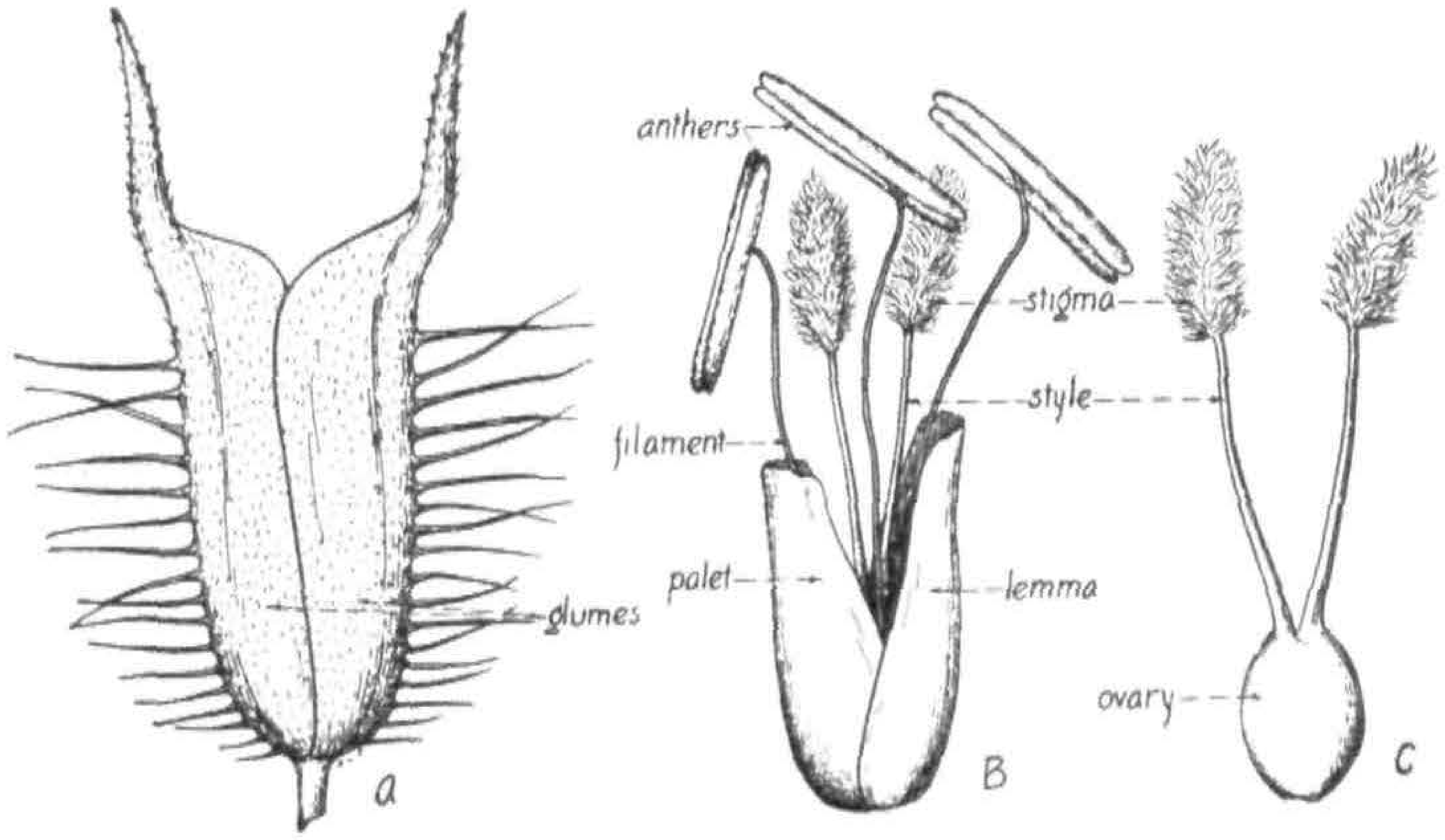


FIG. 89.—Timothy (Phleum pratense). *A*, single spikelet; *B*, spikelet with glumes removed; *C*, pistil.

It is customary to cut timothy while it is in bloom or just past bloom, for at this time the yield of dry matter is greater than at any other stage of maturity. This is due to the loss of leaves and the movement of food materials to the roots which follow the blooming period.

Environmental Relations.—Timothy thrives best in a moist and cool climate; it is not grown south of the 36° latitude, except at high elevations. It is unable to endure hot, dry summers, such as exist in the Great Plains and intermountain areas. It is an important crop at high altitudes in the Rocky Mountains, where it is usually mixed with Alsike clover.

It will grow on both clay and loam soils, and does best when lime is present.

Closely Related Species.—Mountain timothy (*Phleum alpinum*) is common in meadows from Labrador to Alaska, in the mountains of both the East and the West, also Europe, Asia, and temperate South America. The inflorescences are much shorter than those of common timothy, the awn is about one-half the length of the outer glume, and the upper leaf sheath is inflated.

References

Clark, Charles F.: Variation and Correlation in Timothy. Cornell Agr. Exp. Sta. Bull. 279: 1–350, 1910.

Observations on the Blooming of Timothy. Plant World, 14: 131–136, 1911.

Evans, Morgan, W.: The Flowering Habits of Timothy. Amer. Jour. Agr. 8: 299–309, 1916.

Oakley, R. A., and Evans, Morgan, W.: Rooting Stems in Timothy. Jour. Agr. Res., 21: 173–178, 1921.

Webber, H. J.: The Production of New and Improved Varieties of Timothy. U. S. Dept. Agr. Bur. Plant Ind. Bull. 313: 339-381, 1912.

CHAPTER XIX

SACCHARUM OFFICINARUM (Sugar Cane)

Sugar cane is a tall, perennial plant, resembling corn and the sorghums in general habit. The root system is fibrous and rather shallow.

Stems.—The stem is of the usual grass type—divided into a number of joints. The cylindrical, solid culm is 8 to 15 feet high, and 1 to 2 inches in diameter. There are sometimes as many as 60 to 80 nodes. The jointed stem is prolonged into the ground, and the roots arise from the lowermost nodes. This stem arises from the rootstock of the previous year, or, under artificial conditions, from the planted portion of a cane. The buds are found, as usual, in the leaf axils. They are better developed in the lower leaf axils than in the upper. Around the culm, at the bud, are several rows of "dots;" roots arise from these dots when the cane is planted, or when in any way it is brought into contact with the soil. Sugar cane "suckers" readily. The plant is propagated commercially entirely from stems. The whole stalk may be used or only the lower parts of the stools, the so-called "rattoons."

Leaves.—There is a single, broad, clasping leaf at each node.

Inflorescence, Flowers, Fruit.—The inflorescence is a loose panicle, 1 foot or more in length, with numerous branches. The spikelets are arranged in a racemose fashion on slender branches. They occur in pairs, one of which is pedicellate, the other sessile. There are two glumes at the base of the spikelet. Each spikelet is two-flowered; the lower one is

sterile and consists of a palet; the upper is fertile and has a lemma and palet, two minute lodicules, one to three stamens, and a single ovary with two stigmas. There is a tuft of long, silky hairs at the base of each spikelet. The grain

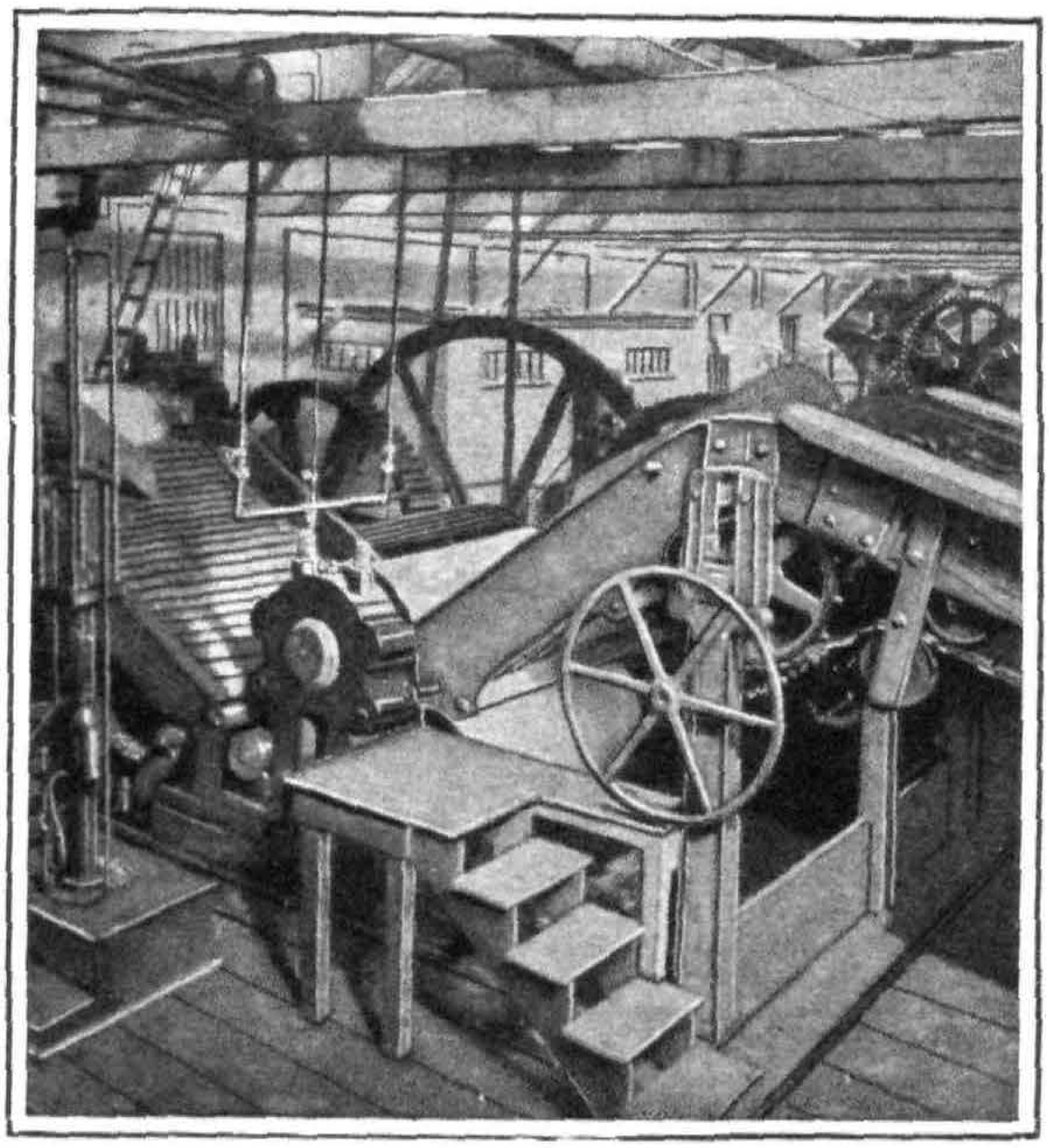


FIG. 90.—Mill where sugar cane is crushed. (*From Essentials of Geography, Second Book. Copyright, 1916, by Albert Perry Brigham and Charles T. McFarlane. American Book Company, Publishers.*)

is small, silky, and of low vitality. Mature grains are seldom produced in cultivated plants and pollen is often infertile.

Geographical.—*Saccharum officinarum* is a native of the tropics. It is now grown as a crop throughout our Southern States and in many other warm regions. It is not a success north of the latitude of 33°. The roots are unable to stand a temperature much lower than 15°F.

Sugar from Sugar Cane.—The canes, stripped of their leaves, are first shredded by revolving spiked clylinders, and then passed between three different sets of rollers, which crush out the juice. About 75 per cent. of the juice is pressed out by the first set of rollers. Between the first and second set of rollers, the canes are sprayed with the heated juice from the third set. About 10 per cent. of the total amount of juice is removed by the second set of rollers. Before reaching the last set of rollers, the crushed material is sprayed with hot water; in this process about 5 per cent. of the total juice is removed. The crushed canes, known as "bagasse," are utilized as a fuel to run the mill.

The juice that flows from the rollers is turbid, due to the impurities which it contains. It is strained, and then milk of lime is added. The limed juice is heated with steam. The impurities unite with the lime, and appear as scum on top or as a sediment at the bottom of the purified juice. The clear juice is run into vacuum evaporators, where it is concentrated to the desired point. The concentrated juice is then pumped into tanks, where crystallization is brought about.

The grain of the sugar is under the control of the one who has the crystallizing pans in charge. A high temperature in the vacuum pans favors the formation of hard-grained sugar; while a low temperature and high vacuum produce a "soft sugar." The mixture of molasses and sugar crystals is termed "massecuite." They are separated by centrifugal action. The sugar crystals are then dried, and packed for shipment.

By-products of Manufacture.—Cane molasses from the manufacture of white and high-grade yellow sugars is used for baking purposes and as a table syrup. Poorer grades are employed in rum and alcohol manufacture, and in stock feeding.

Mention has been made of the fact that the stalks from which the juice has been removed are used as a fuel to run the mill. The refuse that accumulates in the purification process is used as a fertilizer. It is rich in phosphorus and potash.

Production of Cane Sugar.—The world's production of cane sugar during the 1913–1914 campaign was 11,225,000 short tons (excluding Central America). During the same period, the world production of beet sugar was 9,430,145 short tons. Sugar-cane production in the United States is confined almost exclusively to southern Louisiana, and to Texas, immediately adjoining.

Leading Countries in the Production of Cane Sugar, 1913–1914

Country	Short Tons
Cuba	2,909,000
British India	2,566,000
Java	1,541,000
Hawaii	612,000
Philippine Islands	408,000
Australia and Fiji	407,000
Porto Rico	364,000
Argentina	304,000
United States	301,000
Mauritius	275,000

References

Hines, C. W.: A Study of the Root System of the Sugar Cane and Its Application to the Production of Ratoon Crops. The Philippine Agr. Rev., 10: 151–161. 1917.

CHAPTER XX

LILIACEÆ (Lily Family)

Representatives of the lily family are found all over the world, although they are best developed in drier parts of the temperate zone. The family is by no means of as great economic importance as the grass family. A number of representatives are cultivated as vegetables, the principal ones being onions and asparagus. Yucca, lily (*Lilium*), hyacinth and tulip are chief among those cultivated as ornamentals.

Habit, Roots.—Most members of the family are fleshy herbs from bulbs or rhizomes. Some species of *Aloe* and *Dracæna*, however, are shrubs or small trees. In herbaceous forms, the *roots* are mostly fibrous and shallow, sometimes fleshy and extending to considerable depths in the soil.

Stems.—Both *underground* and *aerial* stems are borne. Underground stems in the family are either rhizomes or bulbs. The character of rhizomes has been described (page 75). *Bulbs* are fleshy stems with a very short, usually conical stem upon which are many fleshy, overlapping leaves (Fig. 15). Bulbs, like rootstocks or rhizomes, are storage organs. They are made use of in vegetative propagation. The aerial stems may be leafy or free of leaves for a long distance. In *Yucca*—the soapweed or Spanish bayonet—of the semi-arid sections of the country, the base of the aerial stem is persistent from year to year.

Leaves.—The leaves are mostly linear, seldom divided or toothed, and not divided into petiole and blade.

Inflorescence and Flowers.—There are a number of different types of inflorescences in the family. The flowers are often single or solitary, as in the lilies; or racemose, as in the soapweed and hyacinths; or umbellate, as in onion. The umbellate or umbel-like type of inflorescence consists of many flower stalks of about equal length arising near together on the stem; the outside flowers open first, the inside last, that is, the order of opening is *centripetal.* This is the order of opening in all racemose types of inflorescences. The *perianth* consists of six separate segments, in two whorls of three each, which are very similar in size, shape and color (Figs. 32 and 91). The *stamens* are attached to the receptacle or to the perianth. The *anthers* are usually large and conspicuous. The superior *ovary* is three-celled, has one style and a three-lobed stigma.

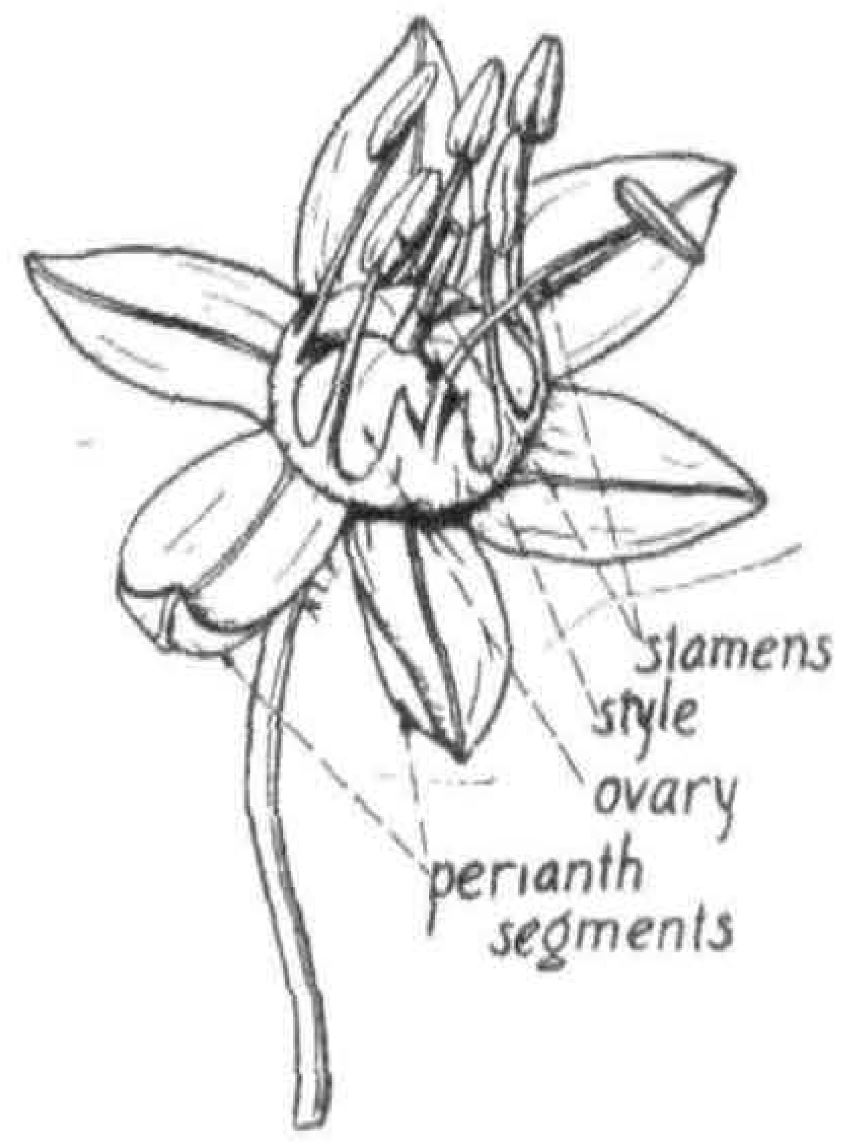


FIG. 91.—Flower of onion (Allium cepa).

Fruit and Seeds.—The fruit is a capsule or berry. The *capsule* is a dry, splitting (dehiscent) fruit with several united carpels. When the carpels split down the middle line as they do in lilies, the dehiscence is said to be *loculicidal.* It is distinguished from *septicidal* dehiscence of capsules, in which the carpels open along the line of their union, as in rhododendron, and from *poricidal* dehiscence in which the carpels open by pores, as in the poppy. The *berry* is a fleshy fruit possessing several to many seeds which are more or less imbedded in the fleshy ovary wall (pericarp).

The *seeds* always possess abundant endosperm, which encloses the embryo. Considerable quantities of oil occur in the endosperm.

ALLIUM

To this genus belong chives, garlic, leek, onion, shallot an(Welsh onion. They are all herbs with a characteristi

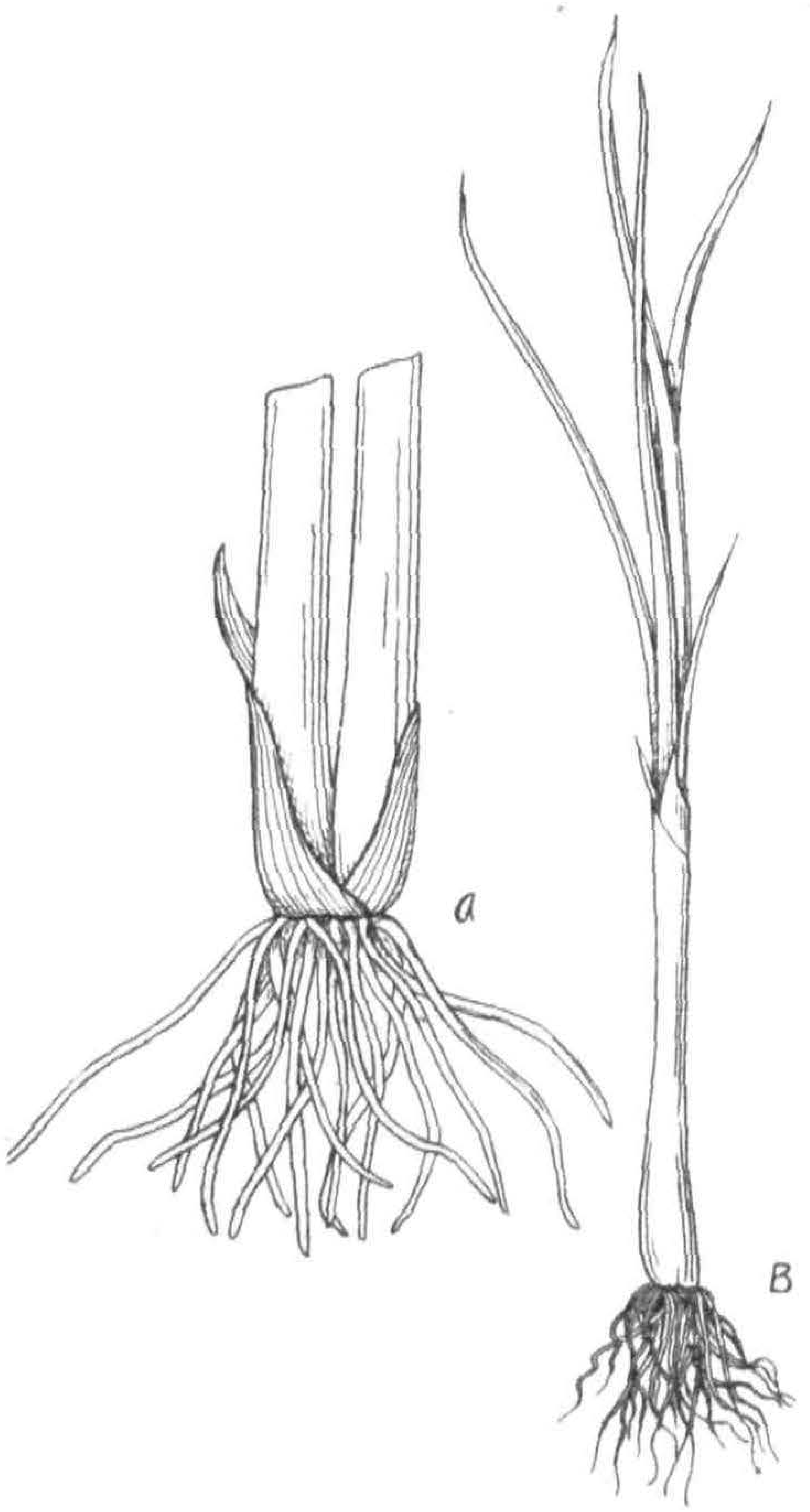


FIG. 92.—*A*, Welsh onion (Allium ascolonicum); *B*, cive (Allium schœnoprasum).

alliaceous odor, which is due to the presence of allyl sulphide.

Roots.—The root system is fibrous and very shallow (Fig.

88). The roots arise from the reduced stem, forming a fibrous tuft.

Stems.—With but few exceptions, species of the genus *Allium* bear bulbs. In chives (*Allium schœnoprasum*), the bulbs are very small (Fig. 92), and in Welsh onion (*Allium fistulosum*) and leek (*Allium porrum*), they are nearly always

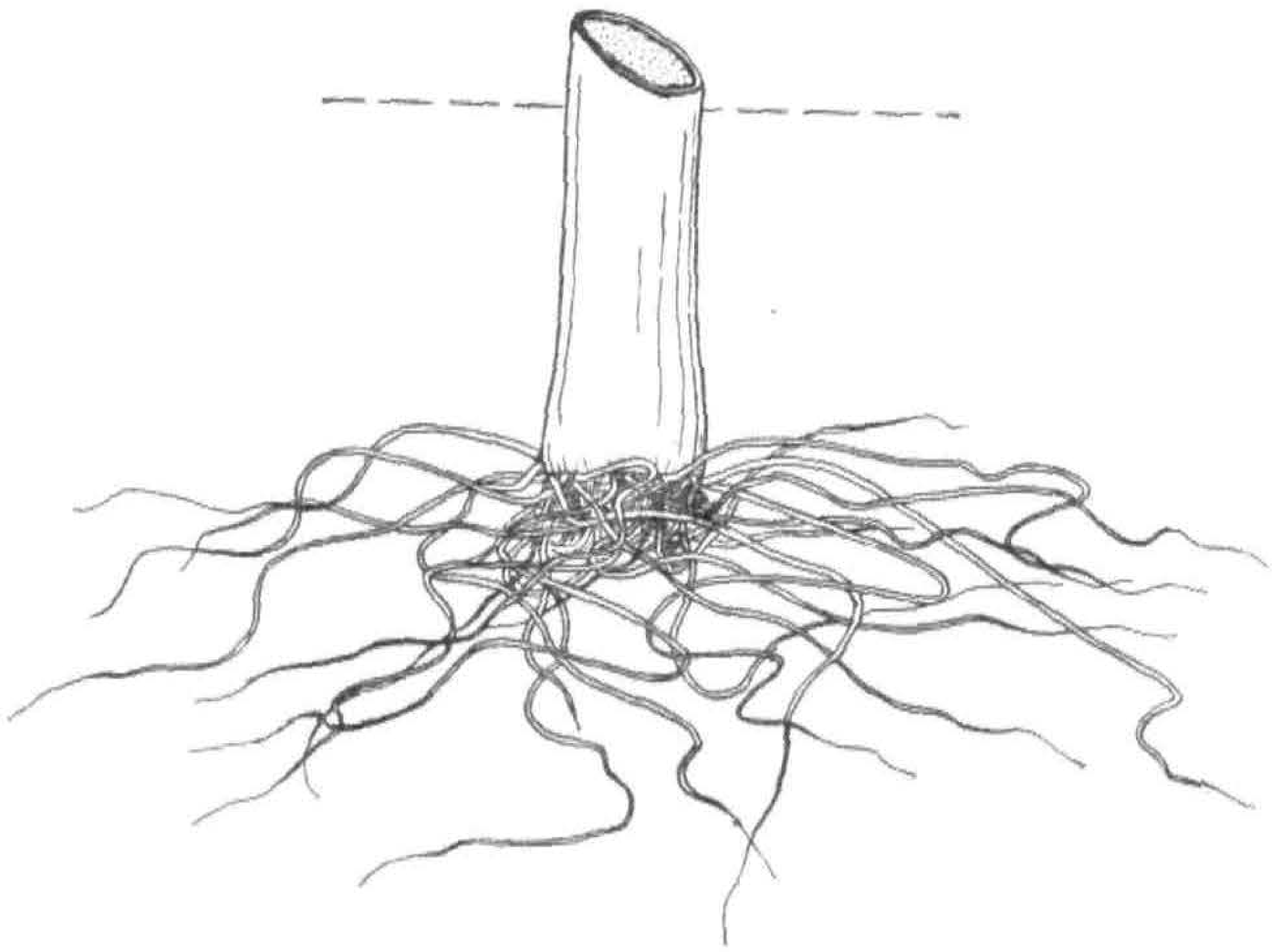


FIG. 93.—Leek (Allium porrum).

absent (Figs. 92 and 93). In the common onion (*Allium cepa*), they are large and well developed. Examination of the mature bulb of the common onion shows it to be made up of the much thickened bases of leaves, attached to a comparatively small, coincal stem (Fig. 15). This is best seen in a median, longitudinal section. From a terminal bud on this small, underground stem, there is sent up a long hollow or solid, leafless stem (Fig. 94) (scape) bearing an inflorescence at the top, which in this case is an umbel. Lateral buds are sometimes borne in the axils of the leaves, and these may also, develop into flower shoots.

Leaf.—The first foliage leaf emerges from a slit in the cotyledon. All leaves are very thick and fleshy, and over-

lapping. There is no petiole. The oldest leaves are on the outside of the bulb, while the younger appear toward the inside. In a longitudinal section of the bulb, it will be noted that these younger leaves, coming from within, are higher on the compressed stem than the older (Fig. 15). The edible

FIG. 94.—*A*, base of stem of common onion (Allium cepa) showing hollow leaves cut across; *B*, cross-section of hollow stem of same; *C*; base of stem of leek (Allium porrum) showing flattened solid leaves; *D*, cross-section of solid stem of same.

portion of the common onion, and of some other species, is the fleshy bases of leaves. In some species, as leek and shallot, the leaves are used as a seasoning in food. The leaves may be either flat or cylindrical (terete), and are sometimes hollow. Onions have been known to bear buds (epiphyllous buds) on their leaves.

Inflorescence (Fig. 95).—The numerous flowers are in simple, terminal umbels. The umbel is subtended by a *spathe*, consisting of two (rarely three) papery bracts. The spathe encloses the entire umbel in the bud. The pedicels are long and slender. There is great variation in the number of flowers in an individual umbel: there may be fewer than a hundred and as many as a thousand. One would expect

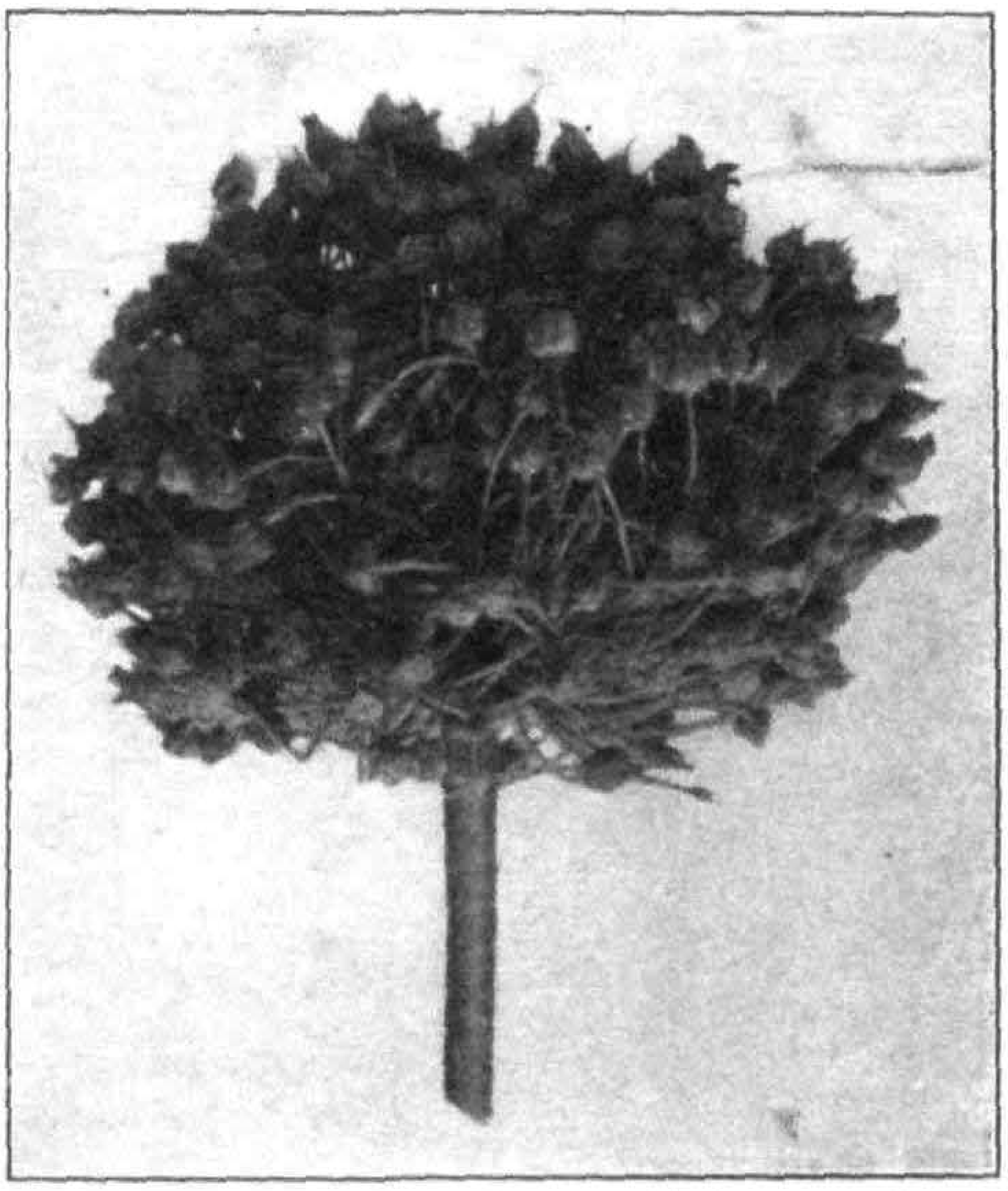


FIG. 95.—Umbel of onion (Allium cepa).

that in the umbellate type of inflorescence (indeterminate type) the oldest flowers would be at the base and the youngest at the top of the floral axis. However, in the onion, adjacent flowers may be in quite different stages of development; young ones may occur at the base, and the old ones at the top.

Flower.—The flowers (Fig. 91) are regular and perfect. The perianth consists of six distinct segments which are very similar as to size, shape and color. The six stamens are

inserted on the bases of the perianth segments. Alternate filaments are usually dilated at the base, and the anthers are oblong, and opening inward (dehiscing inward). The single,

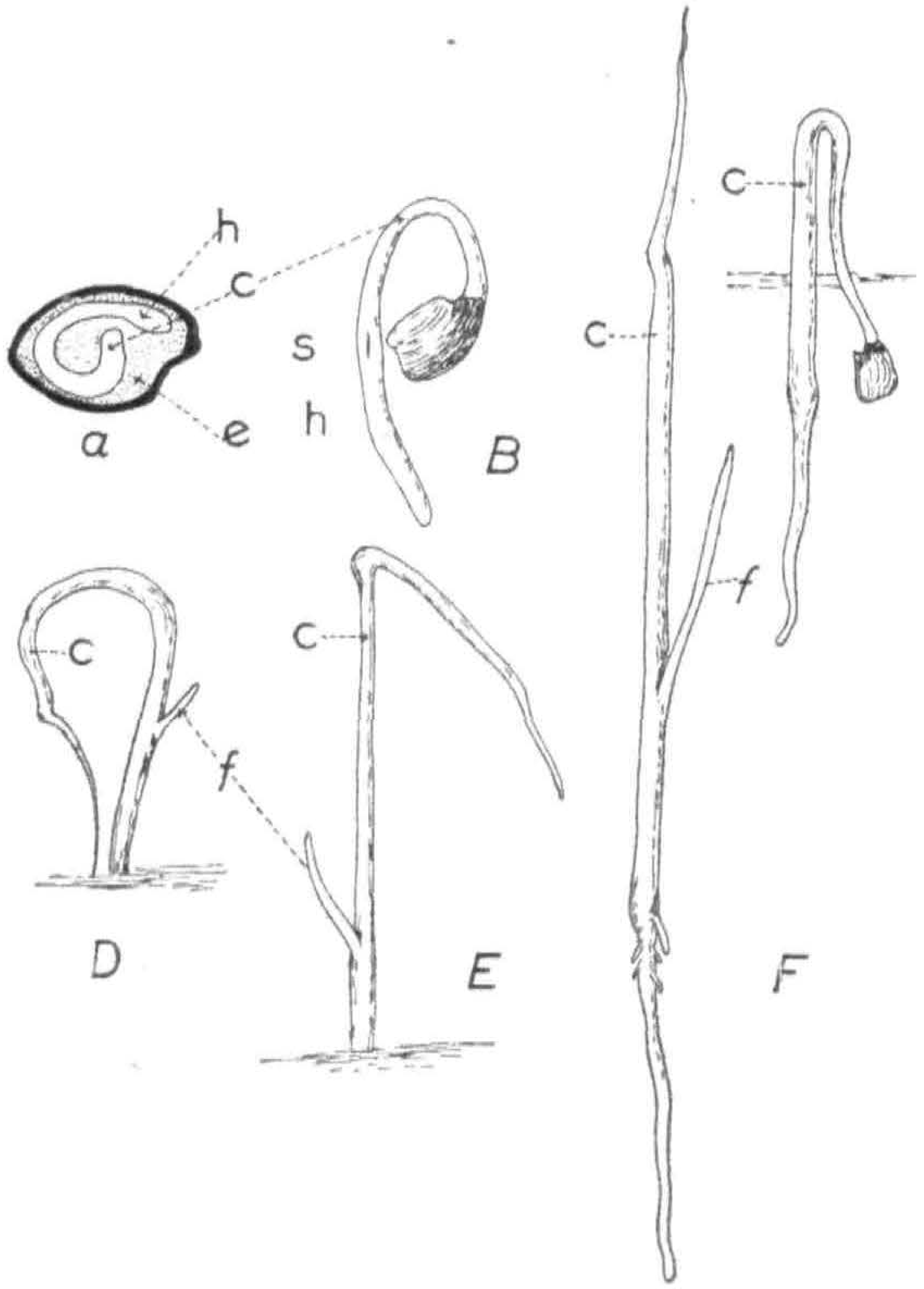


FIG. 96.—Seed and seedling of onion (Allium cepa). *A*, seed; *B*, to *F*, successive stages in the development of the seedling; *c*, cotyledon; *e*, endosperm; *f*, first true leaf; *h*, hypocotyl; *s*, slit from which the first true leaf emerges. *A* considerably magnified. (*After Bergen and Caldwell.*)

superior ovary is imperfectly three-loculed and bears a single filiform style, which may be more or less indistinctly three-cleft at the apex. There is no resting stage in the flower buds of onion, as in most woody flowering plants, but

the floral axis gives rise to flower primordia shortly after the mother bulb starts active growth in the spring of the year.

Pollination.—Species of *Allium* are insect pollinated. The anthers of the flower usually mature before the stigma, although the reverse is sometimes the case. The inner circle of stamens is the first to shed pollen. The style does not attain its maximum length, and the stigma does not become receptive until several days after anthesis. It is of interest to note that the anthers of any whorl do not open simultaneously, but rather in succession, the interval depending upon the temperature and relative humidity. Since the onion is largely insect pollinated, when bulbs of different varieties are planted for seed production, these varieties should be quite a distance apart.

Fruit.—This is a three-celled, membranaceous capsule with loculicidal dehiscence. Two seeds, black in color, are usually borne in each locule of the capsule. The seeds (Fig. 96) are convex on one side and almost flat on the other, and possess a large quantity of oil. The embryo is cylindrical and curved.

Germination of Seed, and the Seedling.—At the beginning of germination, the primary root is forced out by the growth of the curved end of the embryo (Fig. 96). The curved end of the embryo, the cotyledon, comes out of the ground in the form of a closed loop. The tip of the cotyledon remains attacked to the endosperm and seed coat. When the soil is loose, the endosperm and seed coat may be pulled from the ground, but in case it is compact, they remain beneath the ground. The cotyledon absorbs nourishment from the endosperm. When this is used up, the cotyledon tip withers and becomes detached from the seed coat. At the base of the cotyledon, where it joins the hypocotyl, there early appears a longitudinal slit; through this, the first foliage leaf emerges. The cotyledon later disappears entirely.

Geographical.—There are about 250 species of the genus *Allium*, the majority of which occur in boreal America, Mexico and northern Europe. A number are also found in Abyssinia and extratropical Asia. The cultivated onions require cool, moist weather during the early stages of their development, but ripen better if the weather is drier.

KEY TO PRINCIPAL CULTIVATED SPECIES OF GENUS ALLIUM

Leaves flat and solid (Fig. 94).
  Leaves keeled, very narrow, *Allium sativum* (garlic).
  Leaves keeled, very broad, *Allium porrum* (leek).
Leaves cylindrical and hollow (Fig. 94).
  Plants forming a dense clump with very small bulbs, *Allium schœnoprasum* (cive or chives).
  Plants not forming dense clumps; bulbs of considerable size.
    Leaves short, awl-shaped; bulbs in clusters (Fig. 92), *Allium ascalonicum* (shallot).
    Leaves long, rather broad; bulbs not in clusters.
      Bulbs very distinct, generally large (Fig. 15), *Allium cepa* (common onion).
      Bulbs not distinct, usually a mere swelling at base of plant (Fig. 92). *Allium fistulosum*, (Welsh onion, ciboule).

ALLIUM SATIVUM (Garlic)

Garlic is a perennial herb. The bulbs are composed of several small, elongated, egg-shaped bulbils, called "cloves," all of which are enclosed by a whitish skin (Fig. 97). There are often as many as ten bulbils in a single bulb. The scape is from 1 to 2 feet high, round, and possesses alternate, broad-linear, solid, flat leaves. The spherical umbels bear many bulblets among the small, long-stemmed flowers. Seeds and bulblets are borne in the same head. In propagation, the bulblets in the flower head and the cloves are used more commonly than seeds.

Garlic is a native of southern Europe. Both the cloves and leaves are used in seasoning salads and soups, and the stems are also often an ingredient of sausage and other ground meats.

ALLIUM PORRUM (Leek)

Leek is a very robust biennial plant. The bulbs are small. The tall scape is solid and bears broad, solid, keeled leaves (Fig. 94).

Leek is a native of the Mediterranean region.

The edible portions of the plant are the bases of stems and leaves. The stems are blanched and eaten the same as asparagus or as common onions. The leaves are used to season soups, salads and stews.

Important varieties are Large American Flag, Musselburgh, Large Rouen and Monstrous Caratan.

ALLIUM SCHŒNOPRASUM (Chives or Cives)

Chives (Fig. 92) are hardy perennials bearing small, white, narrowly ovoid, clustered bulbs with membranous coats. The scape is stout and up to 2 feet high. The leaves are linear, terete, and hollow, 7 or 8 inches in length and borne in dense tufts. The rose-colored flowers are in dense, globular umbels. Although the plant flowers profusely, it seldom produces seeds. It is propagated by division of the tufts of bulbs.

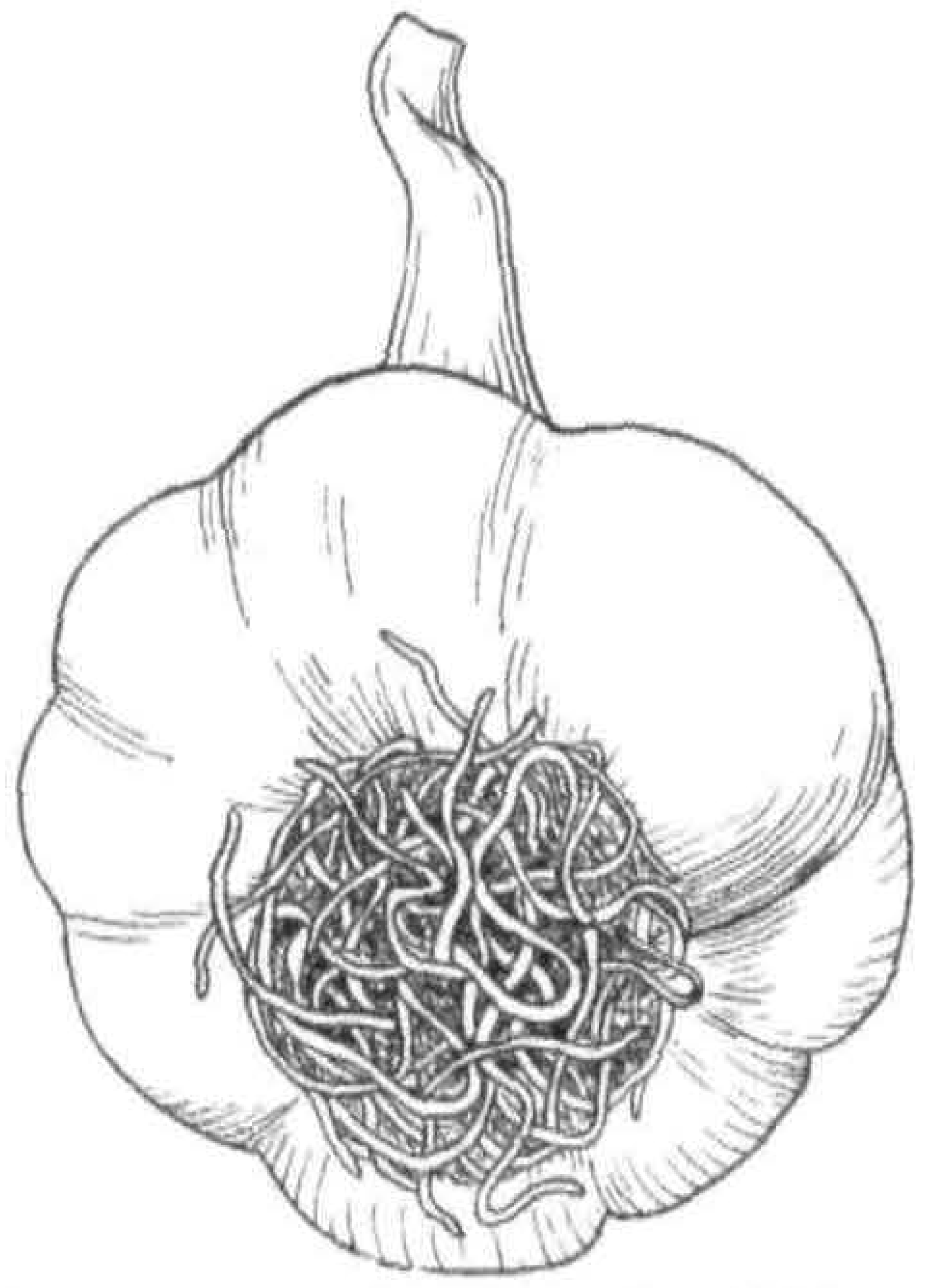


FIG. 97.—Bulb of garlic (Allium sativum). × ½.

Chives are natives of Europe, Asia and North America. In this country, they grow wild from New Brunswick to Alaska, south to Maine, northern New York, Michigan, Wyoming and Washington.

The young leaves are used in the seasoning of soups, omelets, and stews. The plants are also used, ornamentally, in garden borders.

ALLIUM ASCALONICUM (Shallot)

This is a perennial herb with small, oblong-pointed bulbs about 1 inch in diameter and 2 inches long (Fig. 98). The bulbs are borne in clusters, but unlike garlic, are not surrounded by a thin membrane. The leaves are short, cylindrical and hollow. The compact umbels bear lilac or reddish flowers.

FIG. 98.—Shallot (Allium ascolonicum).

ALLIUM FISTULOSUM (Welsh Onion or Ciboule)

This is an annual or biennial with long, fibrous roots. No bulbs are produced, mere swellings occurring at the base of the plant (Fig. 92). The leaves are long, rather broad and hollow. It seeds well.

The plant has been found wild about the Altai Mountains and Lake Baical in Siberia. It is not known how the plant got its name "Welsh Onion."

The leaves are used as a seasoning in stews, soups and salads.

ALLIUM CEPA (Onion)

Description.—The common onion is a biennial with large bulbs, that are usually single. The scape is 2 to 3 feet tall, smooth, and somewhat enlarged near the middle. The leaves are long, broad, cylindrical and hollow (Fig. 94).

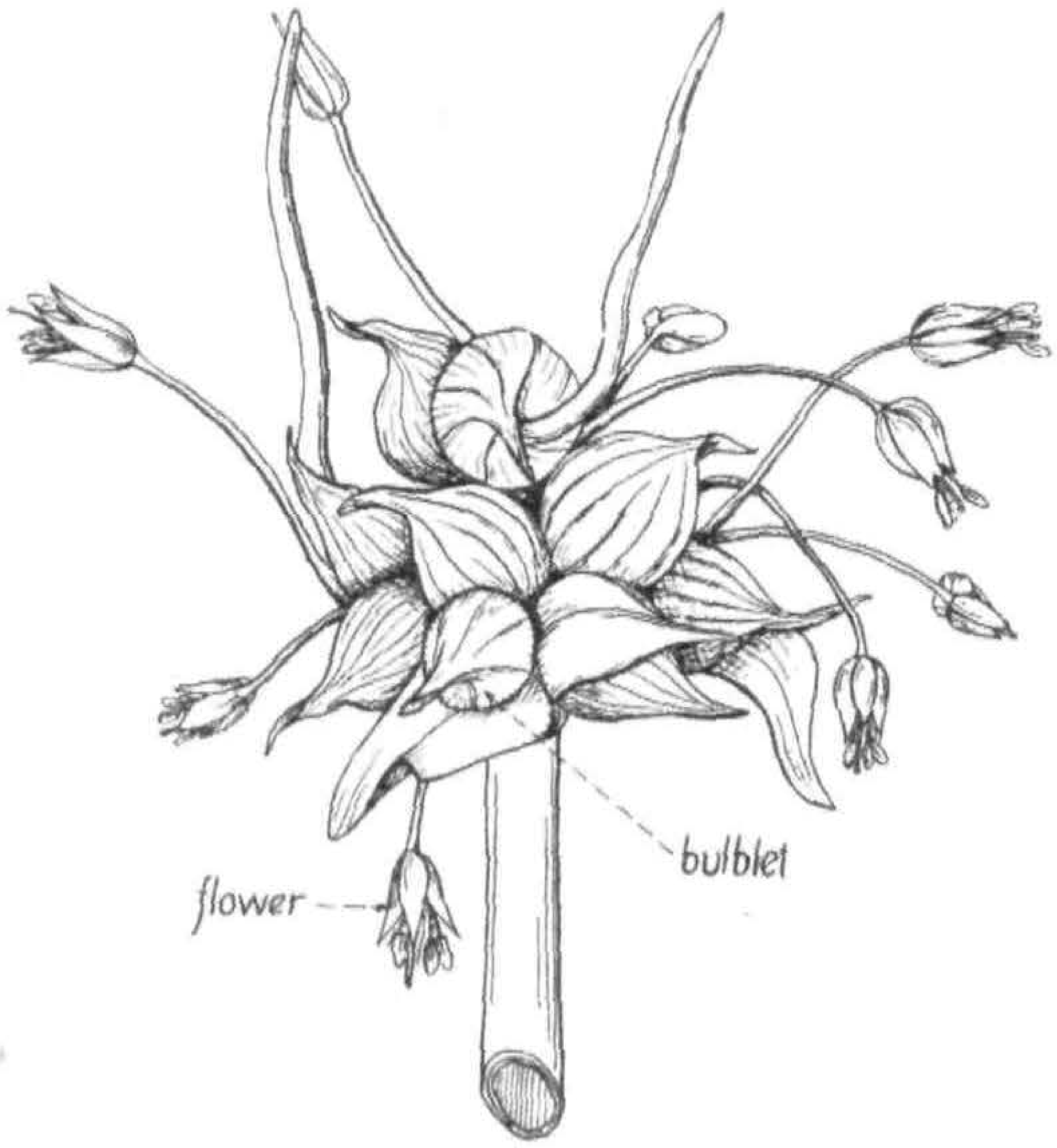


FIG. 99.—Top onions.

History.—The common onion is at present not found in a wild state. Its cultivation dates back to the earliest times in the history of India, Egypt, and China. It was used by Egyptians as a sacrificial offering. By 1390, the onion was

quite extensively used in Europe. The earliest colonists brought the onion with them to America.

Types of Onions.—The varieties of common onions differ quite widely as to manner of propagation, quality, shape, color and size of bulbs, and time of maturity. L. H. Bailey proposes a classification as follows:

1. Propagated by division (*Allium cepa var. multiplicans*).
   Potato onions.
   Multipliers.
2. Propagated by inflorescence bulblets or "tops" (Fig. 95) (*Allium cepa var. bulbellifera*).
   Top onions.
   Tree onions.
   Egyptian onions.

FIG. 100.—Two common types of onions based upon shape of bulb. *A*, globe type; *B*, flat type.

3. Propagated by seeds (*Allium cepa*). (These are also propagated by "sets," which are small bulbs grown from seed and arrested in their development.)

Skin of mature bulb silvery white.
1. Globe onions (Southport White Globe) (Fig. 100).
2. Flat onions (Fig. 100).
   (*a*) Bulbs large (White Italian Tripoli, Silver Skin, White Bermuda, White Portugal).
   (*b*) Bulbs small (Queen).

Skin of mature bulb colored.

1. Globe onions (Southport Yellow Globe, Southport Red Globe, Yellow Globe Danvers).
2. Flat Onions.
   (*a*) Bulbs deep and distinctly red (Red Wethersfield, Red Bermuda).
   (*b*) Bulbs indifferent in color, light red (California Early Red), yellowish or straw-colored (White Bermuda).

The "*multiplier*" *onions* have compound bulbs (Fig. 101), copper-yellow in color, with rather thick skin and mild flavor. When large bulbs are planted, they segregate into a number of bulbs, and each produces six to twelve stalks. The potato onion is a hardy "multiplier," sometimes called

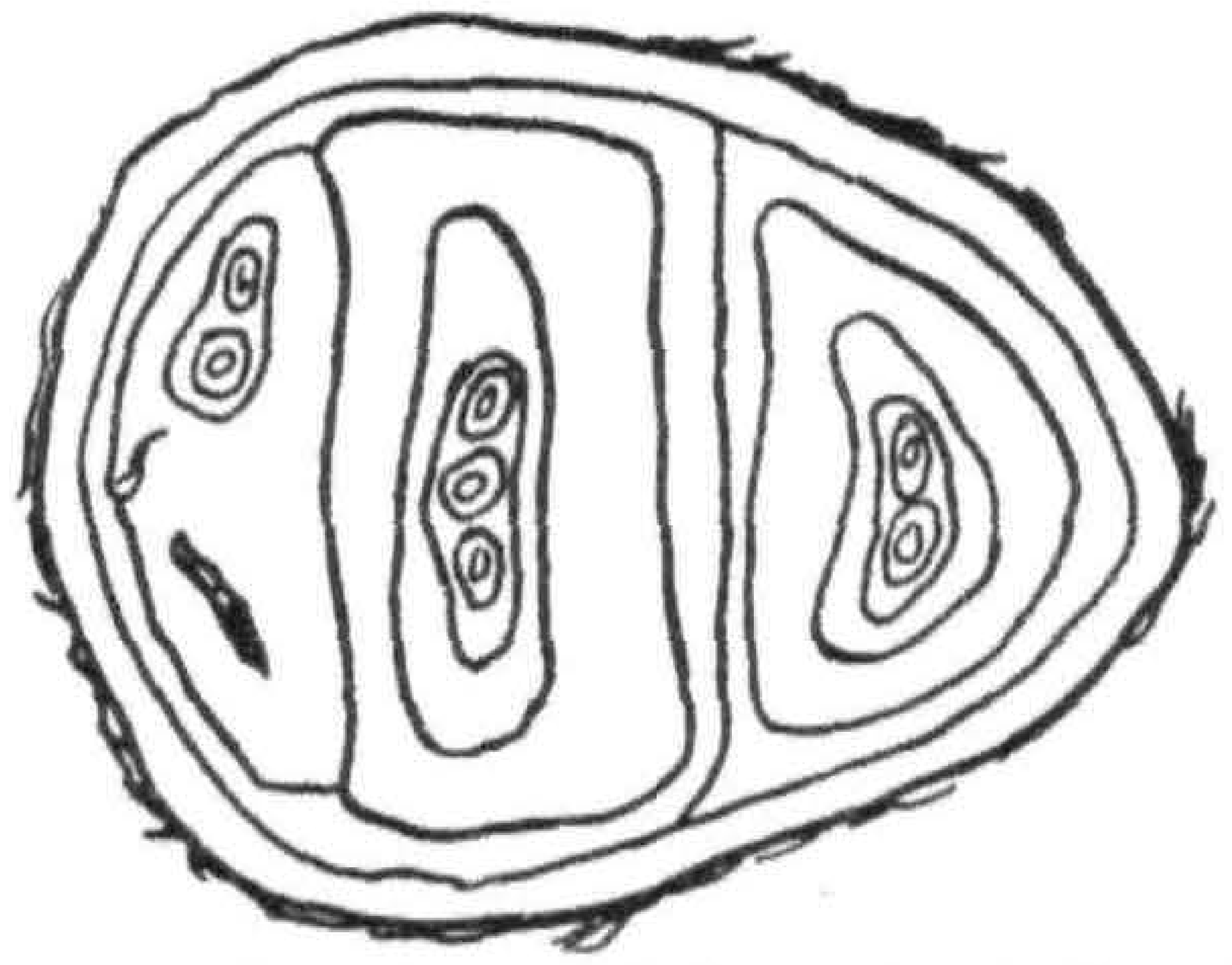


FIG. 101.—Cross-section of a multiplier onion bulb. (*After Bailey.*)

English multiplier. The principal use of the "multiplier" group is in the production of "bunchers" for the early market. There are both white and yellow "multipliers."

In "*top*," "*tree*," and "*Egyptian*" *onions*, clusters of bulblets are produced at the top of the scape. Some primordia develop into flowers and others into bulblets. In some cases, all the primordia may develop into bulblets, and again, almost all may develop into flowers, some of which may produce fertile seed. Bulblets may be produced in separate clusters one above the other on the same stalk. They may germinate while still attached to the inflorescence. It is not clearly known what is the cause of bulblet formation in the inflorescence. Egyptian onions are often called "*perennial tree*

onions." They are valued for fall planting in the North to produce early spring "bunchers." They are a hardy type.

Foreign and Domestic Onions.—There is a rather sharp distinction between "foreign" and "domestic" types of onions. The foreign types include Bermuda, Spanish and Italian onions. As compared with American types, they are larger, less hardy, the flesh is more tender and mild, but they do not keep as well. On account of their tenderness, the foreign types of onions do best in Florida, Texas, and southern California. Seed of the Bermuda onion is produced successfully only in Teneriffe, one of the Canary Islands, off the west coast of Africa. Attempts to grow seed in the United States have given comparatively poor results. The Prizetaker is our best example of a Spanish onion. Important varieties of Italian onions are the Barletta, White Italian Tripoli, White Rocco, and Giant Gibraltar. There are numerous varieties of American onions, well-known ones being as follows: Red Wethersfield, Southport Globe (white, yellow and red), Danvers, White Portugal, Silverskin and Strasburg.

Composition of Onions.—Different varieties of onions vary as to flavor and composition. The foreign types are milder than American types. The flavor is usually more pronounced in bulbs than in leaves or other parts of the plant. The flavor and odor of onions is due to an oil-like organic compound of sulphur, allyl sulphide. The compound is volatile to a high degree, and is broken down by heat; consequently the onion is milder when cooked than when raw. As a rule, white varieties are milder than yellow and red kinds, although there are exceptions to this.

Uses of Onions.—Onions are most commonly used as a vegetable, but in many instances for flavoring purposes. The small varieties such as Queen, Barletta, and American Silverskin are used for pickling. The Egyptian (perennial

tree onion) and multipliers are valued for the production of bunchers. It is considered that the allyl sulphide in onions stimulates the flow of digestive juices and hence they are often recommended for those having a tendency to constipation. Again, on account of the small amount of starch and sugar they contain, onions are made a part of the diet of invalids who are not allowed starchy foods.

ASPARAGUS

Generic Description.—Members of the genus *Asparagus* are all perennial plants with rather fleshy *roots* and short rootstocks. From the latter, rise branching *aerial stems*, which are sometimes annual, as in the common edible asparagus (*A. officinalis*), or perennial as in *A. laricinus*, one of the ornamental asparagi. The stems are erect or climbing, in some instances (*A. falcatus*) reaching a distance of 25 feet or more. The small leaf-like structures along the stem, the so-called "leaves," are in reality *modified stems* (cladophylls) (Fig. 102). They may be slender, as in common asparagus, or broad, as in Smilax. They are arranged in clusters or whorls in the axils of the true leaves. The *true leaves* (Fig. 102) are scales or spines, usually very small. They subtend the branches. The *flowers* are solitary, in small umbels or racemes and arise in the axils of the scales or fascicles of cladophylls. Each flower is mounted on a very slender jointed pedicel. The *perianth* consists of six similar segments which are separate or slightly united at the base. They are persistent in the fruit. *Stamens* are six in number and inserted at the bases of the perianth segments; the filaments are distinct and filiform, and the anthers are ovate or oblong, with introrse dehiscence. The superior *ovary* is sessile, three-lobed, with a short, slender style and three short, recurved stigmas. The *fruit* (Fig. 102)

is a globose berry with two seeds (sometimes more), in each of the three locules. The *seeds* are subglobose, often dark in color. The embryo is cylindrical.

Economic Importance of Genus.—The genus *Asparagus* contains about 150 species distributed throughout tem-

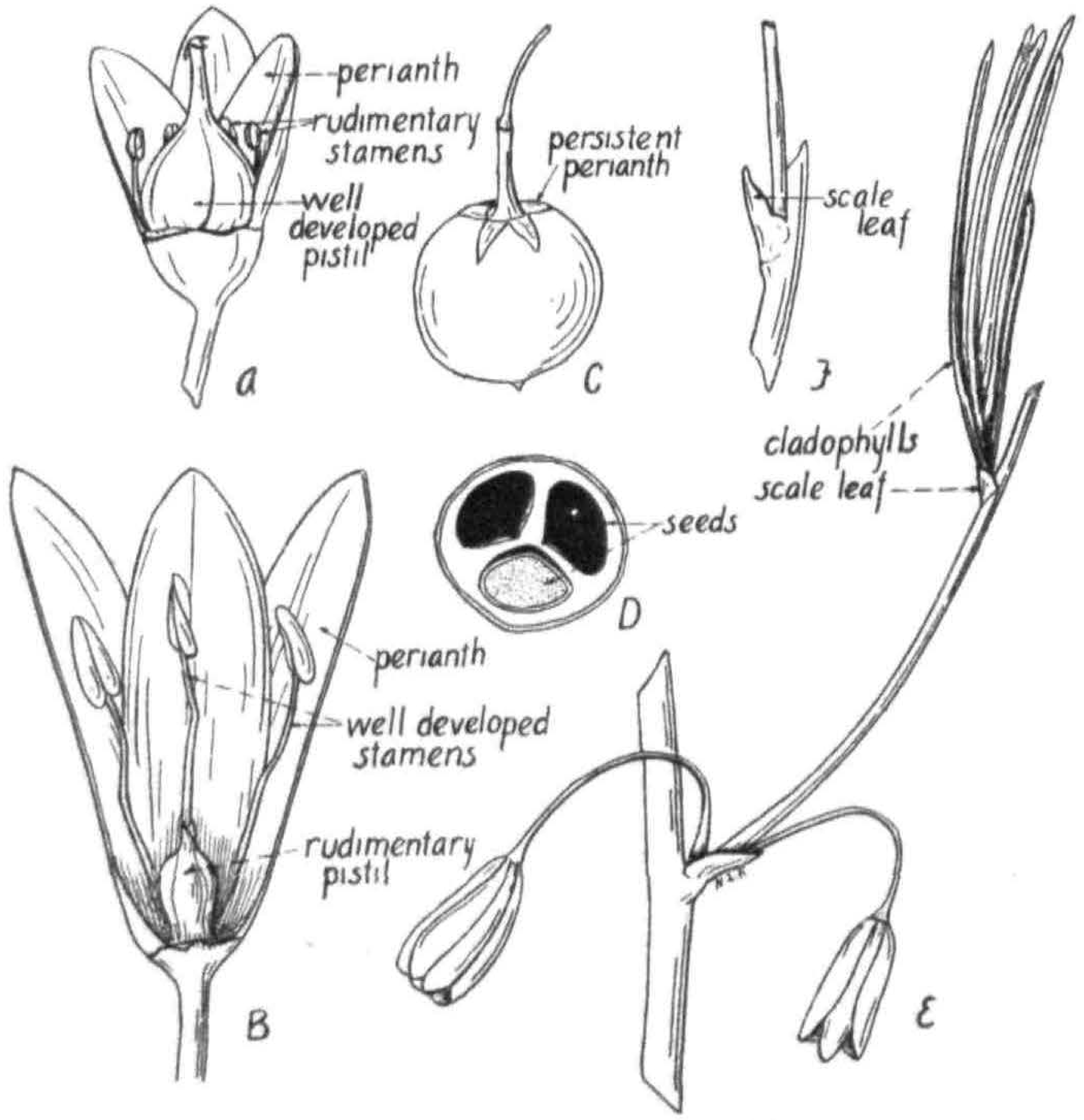


FIG. 102.—Garden asparagus (Asparagus officinalis). *A*, pistillate flower; *B*, staminate flower; *C*, mature fruit; *D*, section of fruit; *E* and *F*, portions of the plant showing method of branching, position of flowers and leaves.

perate and tropical parts of the Old World. There are numerous ornamental species, the most common being *Asparagus medeoloides* (smilax), *A. plumosus* (the plumy asparagus), a climbing plant used for decorative purposes and often called "asparagus fern," and *A. sprengeri*, another "asparagus fern," much used for planting in hanging baskets.

The only edible species of any consequence is *Asparagus officinalis*, the common garden asparagus.

ASPARAGUS OFFICINALIS (Asparagus)

The common garden asparagus is a much-branched perennial herb reaching a height of 3 to 7 feet.

Roots.—There are two kinds of roots in asparagus (1) fleshy, storage roots, and (2) thin, fibrous, absorptive roots. The fleshy roots are produced in large numbers from the sides and under surface of the rootstock. Many of the individual storage roots, in a plant 8 or 9 years old, may extend to a depth of 6 or 8 feet and laterally to a distance of 8 or 10 feet. The great mass of storage roots, however, is confined to the surface three feet. Many storage roots, at least in mild climates, continue their growth at the apex year after year, leaving a definite scar which marks the limits of consecutive season's growth. However, many of the older fleshy roots die each year, and new ones are produced. The new fleshy roots which grow each year arise at a point on the rootstock somewhat above the older ones, which habit of growth accounts for the so-called "lifting of the plants." The thin, absorptive roots are for the most part lateral outgrowth of the fleshy roots.

Stems.—Asparagus bears both subterranean and aerial stems. The underground stems are rootstocks. They are much thickened, branched, and rather woody. The rootstock or "crown" makes an annual growth of 1 to 3 inches. Its extension is chiefly horizontal, taking place at one or both ends. The rootstocks send up aerial shoots (Fig. 105). These at first are thick and fleshy ("spears") and form the edible portion of the plant. The scales borne on these fleshy shoots are true leaves. At length, the stems become much branched. The filiform cladophylls (Fig. 102) are mostly

clustered in the axils of the minute scales. They perform the function of leaves, as is evidenced by their green color.

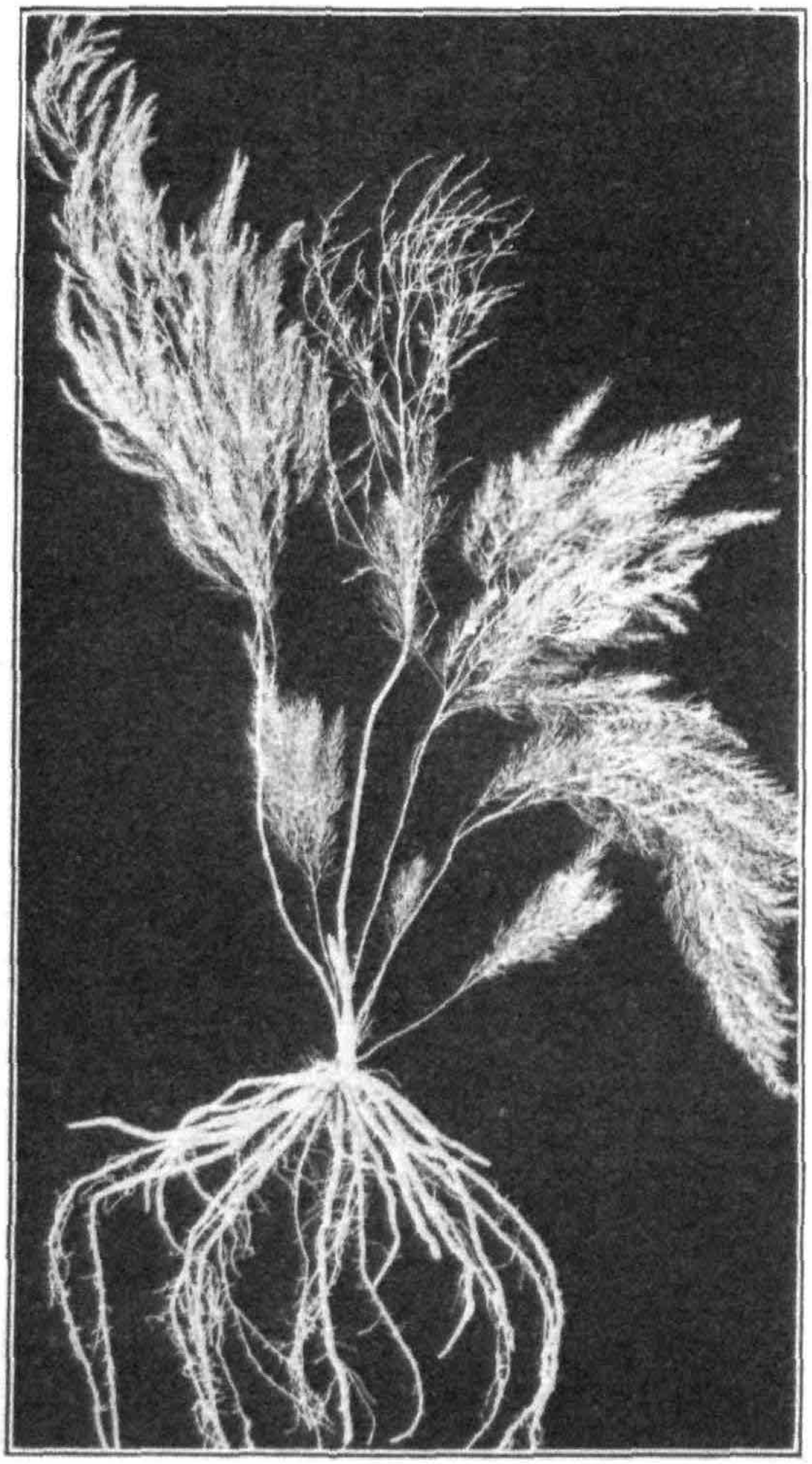


FIG. 103.—Asparagus plant (Asparagus officinalis) at the end of the first season's growth, from seed.

From the time of seeding, it is usually three or four years before the rootstock is vigorous enough to allow cuttings to

be made. However, good crops have been produced two years after seeding. The plant may be propagated by division of the rootstocks, but the common method is by seeding.

Leaf.—The true leaves (Fig. 102) are minute scales subtending the whorls of cladophylls. They do not perform leaf functions.

Flowers.—The flowers are small, drooping, greenish-yellow and usually solitary, but sometimes in twos or more at the

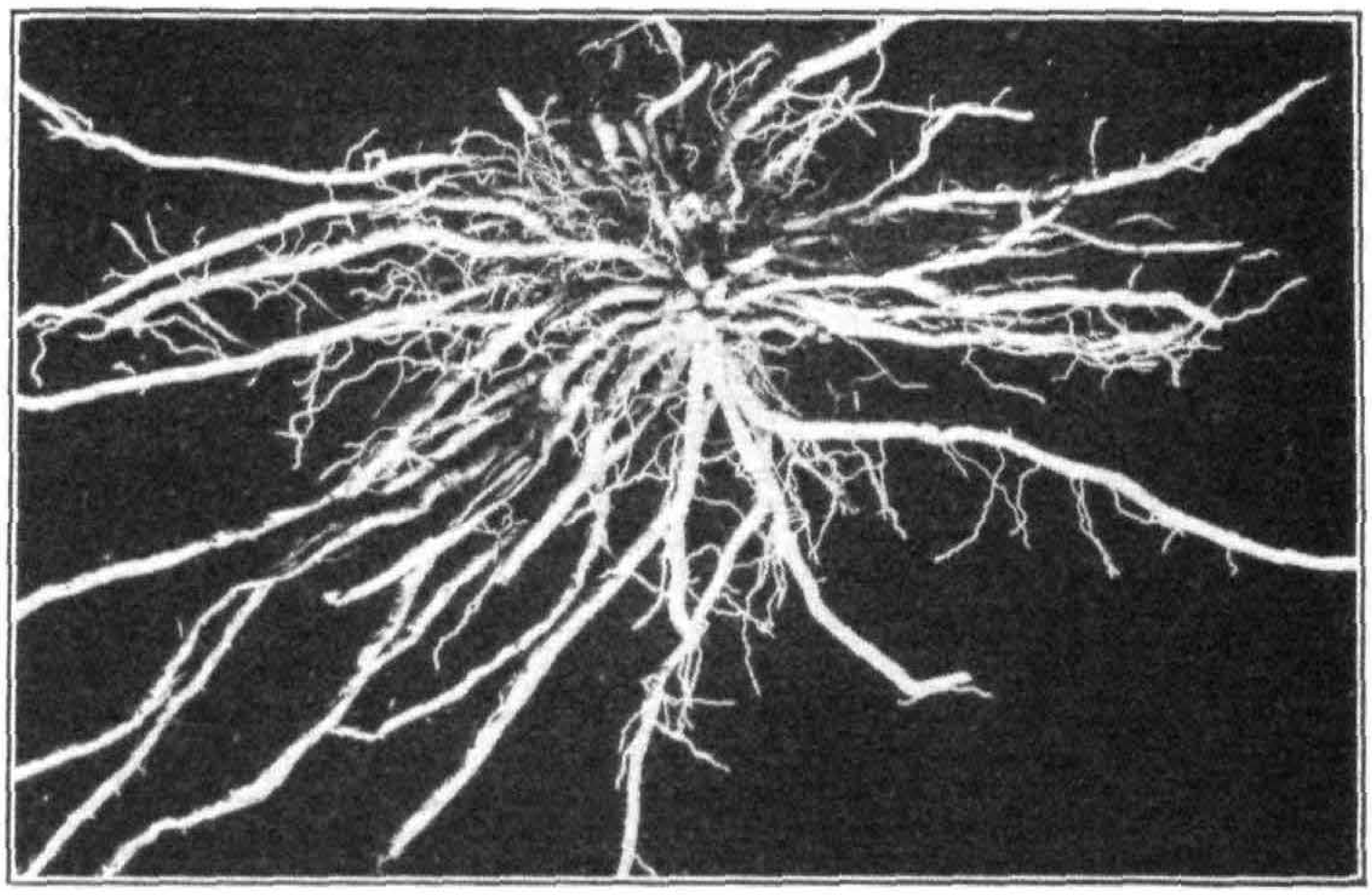


FIG. 104.—Root system of a one-year old asparagus plant (Asparagus officinalis.)

nodes. Each flower is borne on a short, slender jointed pedicel (Fig. 106). The perianth is campanulate (bell-shaped), about 6 millimeters long, the segments being linear and obtuse. The stamens are shorter than the perianth lobes. The single ovary has a short style, a three-lobed stigma and three locules. Common asparagus is diœcious—staminate and pistillate flowers are borne on different plants. Hermaphroditic flowers sometimes occur, however. The staminate flowers (Fig. 102) are slightly larger than pistillate ones. Staminate flowers bear six well-developed stamens

and a very short, rudimentary pistil. Pistillate flowers (Fig. 102) have six rudimentary stamens and a single well-developed pistil. Such flowers are practically unisexual.

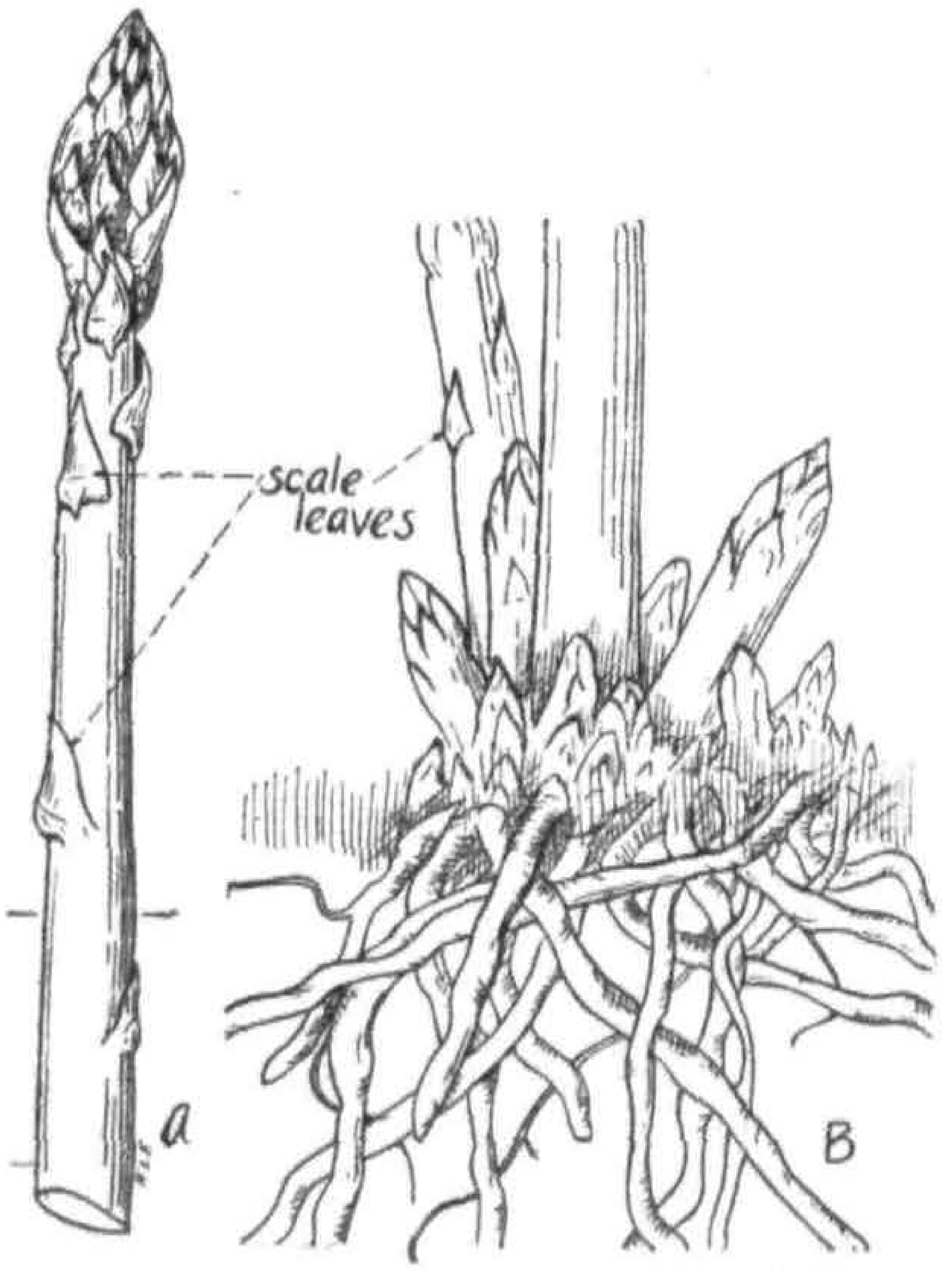


FIG. 105.—Garden asparagus (Asparagus officinalis). *A*, young shoot or "spear;" *B*, thick, fibrous roots and young shoots arising from "crown."

It has been shown that staminate plants are more productive than pistillate ones. Green, in determining the relative productiveness of pistillate and staminate plants obtained the following results:

PRODUCT FROM FIFTY PLANTS EACH, STAMINATE AND PISTILLATE

	Fifty staminate plants, ounces	Fifty pistillate plants, ounces
First period, ten days	37	21
Second period, ten days	104	68
Third period, ten days	266	164
Fourth period, ten days	203	154
Total for season	610	407

This shows a gain of the staminate plants over the pistillate plants of about 50 per cent. for the whole season, the greatest difference being in the first period. Hence, it seems to show

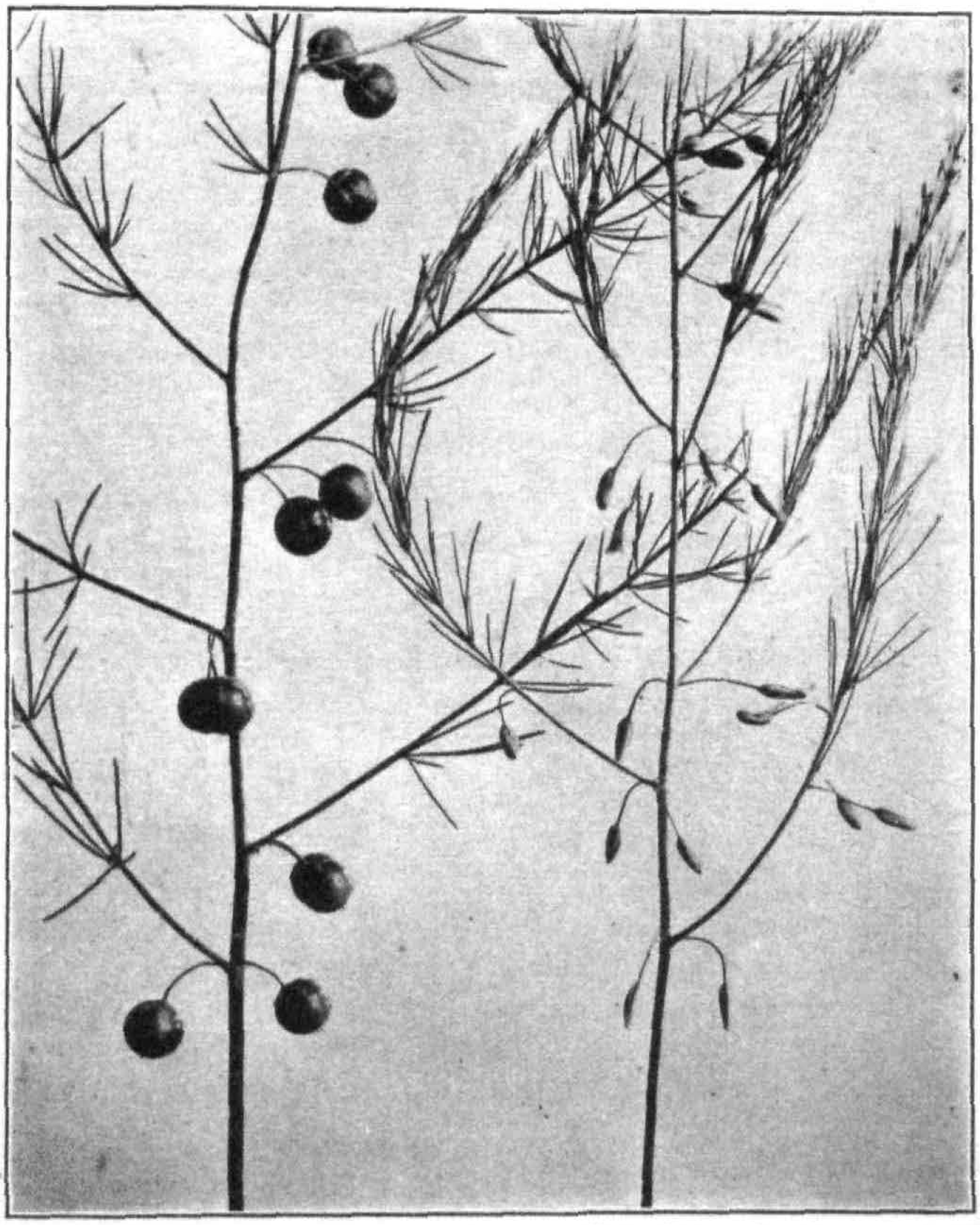


FIG. 106.—Garden asparagus (Asparagus officinalis). Portion of pistillate plant in fruit, on left; and of staminate plant in flower, on right.

that staminate plants are earlier and more productive than pistillate ones. Fruit production makes a greater demand for food than does the formation of stamens. It is for this reason that staminate plants are able to produce a greater

growth of "spears" than pistillate ones. In commercial fields, there is approximately an equal number of staminate and pistillate plants.

Pollination.—Common asparagus is insect-pollinated. The nectaries are small and concealed at the base of the perianth. Staminate flowers are first to open.

Fruit.—This is a red, spherical berry (Fig. 102) with three cells, each of which usually contains two seeds. The perianth is persistent in the fruit. The dark, somewhat triangular seeds run about fifty to a gram. They preserve their germinating power for four or five years, and may even retain their vitality when soaked in water for a year. In California, the plants may produce fruits the first year from seed, but in many other sections, the plants do not begin to produce seed until they are two years old. It is held that the best seed comes from the lower branches of the plant. The asparagus seed has a small, cylindrical embryo surrounded by a considerable quantity of hard, corneous endosperm. The cells of the endosperm have thick, pitted walls of hemicellulose, and are rich in stored fats.

Geographical.—Common asparagus grows wild in Europe and Asia and has escaped from cultivation in this country, often occurring as a weed in fields and along roadsides. The plant has been under cultivation for over 2,000 years. It is cultivated under a wide range of temperature conditions.

Types and Varieties.—Two sorts of asparagus are sold on the market, green asparagus and blanched asparagus. Green asparagus has a more delicate flavor and is quite generally considered the more desirable. Blanched asparagus has a much thicker stalk than the green sort. It must be understood that these two market types of asparagus are simply the result of cultural methods, and may be produced from the same variety. To produce etiolated or blanched asparagus, the plants are banked or ridged up with soil, so that they

must make an additional growth of 4 to 10 inches before they come to light. The shoots that develop in the soil are, of course, whitish.

The number of American varieties of asparagus is small. The most common of these are Conover's Colossal, Palmetto, Martha Washington, Mary Washington, Barr's Mammoth, Eclipse and Columbian Mammoth White. The Palmetto is grown most in the south, and is well-known on account of its resistance to asparagus rust (*Puccinia asparagi*). Martha Washington and Mary Washington varieties are also rust resistant.

Uses.—Asparagus has become one of the most popular of the perennial vegetable crops. Many home gardens have an asparagus bed. The commercial acreage, however, is limited to a few states, the principal ones being California, New Jersey, Illinois, South Carolina, Georgia and Massachusetts. The Delta section of northern California is the leading asparagus district of the United States, from which both green and canned asparagus is shipped in car load lots. As a rule the tender shoots are eaten fresh, but large quantities are also canned each year. The principal canning factories are located in California and on Long Island, New York. A method has been devised by which the soft pulp of the asparagus plant is separated from the fiber and canned in the form of a thick paste. In European countries, particularly, asparagus is dried. In this form it keeps indefinitely.

References

Bailey, L. H.: Preliminary Synopsis of Onions and Some of Their Allies. Rep. of Prof. of Hort. and Landsc. Gard., 26th Ann. Rept. State Bd. Agr. Mich., 94–98, 1887.

Goff, E. S.: Onion. 6th Ann. Rept. N. Y. State Agr. Exp. Sta., 190–214, 1887.

Green, W. J.: Asparagus. Ohio Agr. Exp. Sta. Bull. 9 vol. 3 (second series), 241–244, 1890.

Gross, A. R.: American Onions. Proc. Soc. Prom. Agr. Sci., 115–132, 1901.

CHAPTER XXI

MORACEÆ (Mulberry Family)

The mulberry family has about 925 species in 55 genera, occurring in tropical and temperate regions of both hemispheres. It possesses a number of plants of considerable economic importance. Several Asiatic species of the genus *Ficus* yield a sap from which rubber is made. *Ficus carica* is our cultivated fig. The India rubber plant of greenhouses and in homes is *Ficus elastica*. *Artocarpus communis* is the well-known bread-fruit of the tropics. *Toxylon pomiferum* is the osage orange, a tree whose wood is valuable for wheels, posts and other small articles; it is also planted for ornament. The paper mulberry (*Papyrus papyrifera*), is a native of Asia. Its bark is of value in paper-making. Other genera of importance are *Morus* (mulberry), *Humulus* (hop), and *Cannabis* (hemp).

Description.—Members of this family are trees, shrubs, or herbs with a milky sap. The *buds* may be naked or scaly. The *leaves* are petioled (stalked), stipule-bearing, and borne oppositely or alternately on the stem. The *flowers* are in ament-like spikes or heads on stalks which arise in the axils of leaves. An ament is a spike-like inflorescence each flower of which is subtended by a conspicuous bract. The flowers may be monœcious or diœcious. In the *staminate flower*, the calyx is three- to six-lobed or parted, the petals are absent, and the stamens are one to four, inserted at the base of the calyx. The filaments are thread-like, and erect or inflexed in the bud. In the *pistillate flower*, the calyx consists of three to five partly united sepals. The single superior

ovary is one- to two-celled and bears one to two styles. The *fruit* is drupe-like in mulberries, an achene in hops and hemp, and a synconium in figs.

Key to Principal Genera

Trees or shrubs.
  Flowers not in a receptacle; buds scaly, *Morus* (mulberry).
  Flowers inside of a hollow receptacle; buds naked, *Ficus* (fig).
Herbs.
  Erect herbs, *Cannabis* (hemp).
  Twining herbs, *Humulus* (hop).

MORUS (Mulberry)

Habit of Plant, Stems.—Mulberries are trees or shrubs with milky sap and scaly bark. The *branches* are slender and cylindrical. The winter buds are scaly.

Leaves.—The *leaves* are conduplicate (Fig. 107) in the bud, alternate, serrate, three-nerved, often deeply lobed, and deciduous. The stipules fall soon after development. The

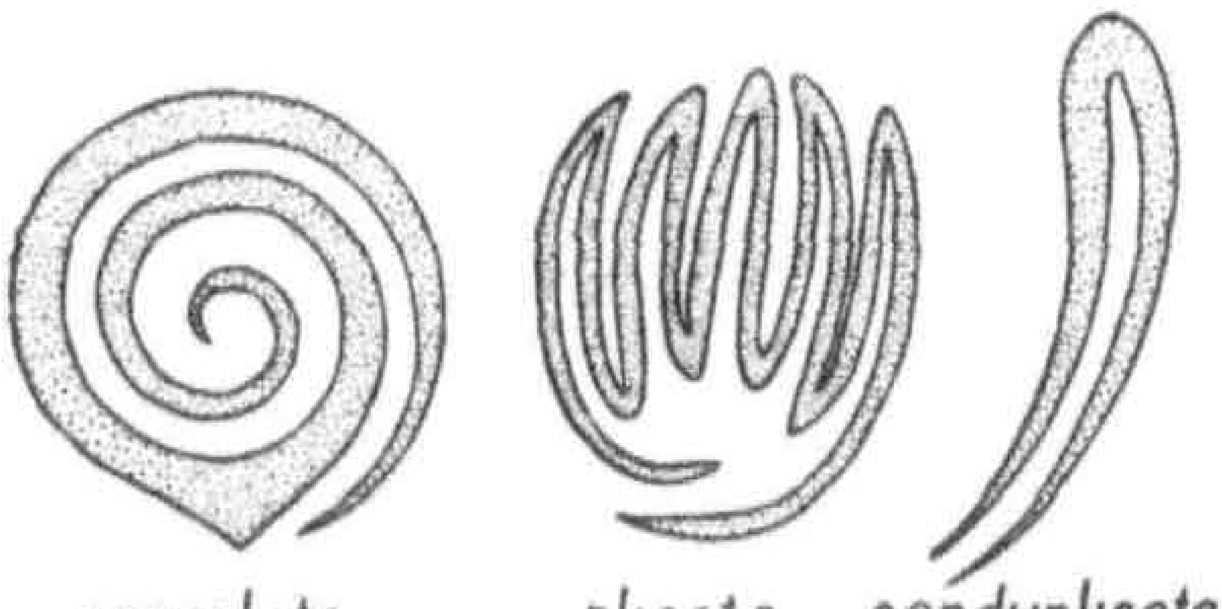


Fig. 107.—Three principal types of vernation.

leaves on one shoot may be relatively entire, while those on another may be moderately or deeply and irregularly lobed.

Inflorescences.—The flowers appear rather early in the season in the axils of the lower leaves. The staminate and pistillate inflorescences may be on different branches of the same tree (monœcious) or on different trees (diœcious).

The *staminate inflorescences* are long, cylindrical catkins. They soon fall. The calyx of the staminate flowers is deeply

divided into four rounded lobes. The three or four stamens are inserted at the base of the calyx, beneath the rudimentary pistil. The filaments are thread-like, inflexed in the bud and uncoil like a spring at the moment of anther dehiscence. The two-celled anthers open lengthwise and shed their pollen toward the inside of the flower (introrse dehiscence).

The *pistillate inflorescences* are short, dense catkins. The flowers in these have a deeply four-lobed calyx, the two outer lobes being the broader. All the calyx lobes are persistent, become fleshy, and enclose the ovary in the fruit. The sessile ovary possesses one cell, and a single style divided almost to the base into two very slender, hairy stigmas. Both staminate and pistillate inflorescences develop from buds which are borne laterally. When the bud unfolds it produces a leafy shoot in the leaf axil of which the inflorescences arise.

Fruit.—Each ovary develops into a nutlet bearing remnants of the styles at the tip and enclosed by the thickened, juicy calyx lobes. There is a single seed within each fruit. However, the mulberry "fruit" as commonly understood, is not a single drupe-like structure, as given above, but an aggregate of these, *i.e.*, an entire pistillate flower cluster. The single fruits are very much crowded together, making up a collection, which commonly goes by the name "mulberry."

Other "Mulberries."—The so-called paper mulberry (*Papyrus papyrifera*), a native of eastern Asia and now planted for ornament in many parts of eastern and southern United States, may be easily distinguished from the true mulberries (*Morus*) by its non-edible globular fruit and the occurrence of its pistillate flowers in heads. In some sections of the country, the "flowering raspberry" (*Rubus odoratus*) is confused with and often called a "mulberry." It is true that the fruit of this has some resemblance to a mulberry

"fruit," but instead of bearing its single drupe-like fruits along an axis, the true drupes of the raspberry are borne on a receptacle. The "fruit" of the mulberry is a collection of one-seeded fruits developed from a number of separate flowers in a dense inflorescence, while the raspberry "fruit" represents the matured ovaries of a number of pistils belonging to a single flower.

Geographical.—The genus *Morus* is a native of eastern North America, higher altitudes in Mexico, Central America, Western South America, Asia, Japan, and the Indian Archipelago.

KEY TO PRINCIPAL SPECIES OF GENUS MORUS

Leaves smooth beneath, sometimes slightly hairy on the veins.
- Fruit white or pinkish; leaves becoming light green above, *Morus alba* (white mulberry).
- Fruit black; leaves becoming dark green and shining above, *Morus nigra* (black mulberry).

Leaves hairy beneath; fruit red or purplish, *Morus rubra* (red mulberry).

MORUS ALBA (White Mulberry)

Description.—This is a low-branched tree, sometimes reaching a diameter of 2 feet. The slender, round twigs are at first hairy, later becoming light grayish brown. The *leaves* are light green, with prominent whitish veins, and variously lobed or divided. The staminate *inflorescences* are 1 to 2 centimeters long, slender and drooping. The pistillate ones are from ½ to 1 centimeter long. The *fruit* is white or pinkish in color, 1 to 2 centimeters long, and poor in quality.

Geographical.—The white mulberry is a native of Asia, probably of China. It has spread throughout Europe and has also become naturalized in eastern United States.

Types and Varieties.—Economic Importance.—There are a number of types and varieties of the white mulberry. According to L. H. Bailey, the following are forms or offshoots of *Morus alba: Morus alba* var. *tartarica* (Russian mul-

berry) and *Morus alba* var. *venosa*. The Russian mulberry is a very hardy, low, bushy tree with small fruit which varies in color from white to red and almost black. It is an important wind-break and shelter-belt tree in the Great Plains. Teas' weeping mulberry is an ornamental variety of the Russian. *Morus alba* var. *venosa* (*M. nervosa*) is an ornamental curiosity bearing jagged leaves with white, prominent veins.

Morus multicaulis (*M. alba* var. *multicaulis*) was introduced into America in 1826 and, for a while, gave a great impetus to the attempts to grow silkworms. It is a small tree with rough, long-pointed leaves.

The chief horticultural varieties of the white mulberry are: New American, Trowbridge, Thorburn and Downing. The Downing is supposed to be a variety of *M. multicaulis*. However, the so-called Downing of most nurserymen is the New American.

Early Attempts in the United States to Grow Silk.—The white mulberry has been cultivated from the earliest times, chiefly for feeding the silkworm. In 1621, mulberries were introduced into Virginia by the London Company with a view of establishing the silk industry in the New World. Early attempts to grow silk were made not only in Virginia but in Carolina, Georgia and Connecticut. After the Revolution, early in the 19th century, silk culture was again agitated. There existed what has been called "*The Morus multicaulis mania.*" This species was introduced into America in 1826, and since it was thought to be the source of the renowned Chinese silk, soon gained wide fame here. The "craze" died down in about 1836, and since that time, there has been little effort to grow silk in North America upon a commercial scale.

Uses.—As has been said, the white mulberry is the one upon which silkworms are raised. In the Old World the

wood of the white mulberry is used for various purposes. The roots furnish a yellow dyestuff. In western Asia the fruit is ground into a meal for food.

MORUS NIGRA (Black Mulberry)

Description.—The black mulberry often attains a height of 40 to 60 feet and a diameter of 1 to 2 feet. The numerous branches are slender, slightly hairy at first, but later become smooth and brownish gray. The *leaves* are dark, dull green, large, pointed at the apex, rounded or heart-shaped at the base, and the teeth rather small and close together. The staminate *inflorescences* are 1 to 2 centimeters long. The pistillate inflorescences are from 5 to 8 millimeters long. The *fruit* is black, 1 to 2 centimeters long and has a deep red juice.

Geographical.—*Morus nigra* is a native of Asia, probably of Persia. It has become naturalized in various parts of Europe and in the United States. In this country, it occurs in the Southern States and on the Pacific coast.

Varieties.—The black mulberry has always been the principal fruit-bearing mulberry in Europe and, in an early day, in America, but it is less tender than our native red mulberry (*Morus rubra*), and hence has been replaced by the latter, especially in the north. The Black Persian variety of the Southern States and California belongs to this species.

Uses.—Over central and eastern Asia the black mulberry is a common and rather valuable fruit, and large quantities are dried. The wood is used like that of the white mulberry. The juice of the ripe fruit has medicinal value. The fruit of all mulberries is relished by hogs and poultry, and it is the practice in some localities to plant mulberry trees along fences enclosing pastures or poultry yards.

MORUS RUBRA (Red Mulberry)

Description.—This is the largest of the mulberry trees, reaching a height of 60 feet and a diameter of 5 to 7 feet. The *twigs* are slender, dark green, with a reddish tinge, but finally become dark brown. The *leaves* are large, those on young shoots deeply lobed, and with oblique and rounded sinuses, in the bases of which there are no teeth; they are rounded or heart-shaped at the base, singly or doubly toothed or three-lobed, and with a rough upper surface and a soft lower surface. The staminate *inflorescences* are slender and cylindric. The pistillate inflorescences are much shorter than the staminate ones. The *fruit* is bright red, becoming nearly black, sweet and juicy, and about 1 centimeter long.

Geographical.—The red mulberry is a native of North America. It grows from Massachusetts to southern Ontario, Michigan, and southeastern Nebraska, eastern Kansas and southward to Florida and Texas. It is most abundant and reaches its largest size in the Central States.

Varieties and Uses.—There are a number of varieties of the red mulberry, all of which are more hardy than those of the black mulberry. The principal horticultural varieties are Hicks, Johnson and Stubbs. The wood is used for posts and fencing, but finds its greatest usefulness in the making of shoe lasts, churns and cooperage material.

HUMULUS (Hop)

HUMULUS LUPULUS (Common Hop)

Root.—The root system of the common hop plant is large as compared with above ground parts. This holds true in both young and old plants. The roots extend to considerable depths in the soil and also spread horizontally in the surface layers. They give rise to a fine network of small rootlets. Older roots become covered with a reddish-brown bark.

Stems.—The common hop is a perennial, herbaceous, climbing plant from an underground stem, a rootstock. These rootstocks may become quite woody. They are commonly used for propagation. Cuttings from them readily form numerous adventitious roots. Hop plants send out, near the ground line, "runners" which extend several feet. These are cut into pieces, possessing two or more buds, and used for propagation. They are known in hop culture as "roots." However, they are stems and not true roots.

The aerial stems, commonly known as "bines," die back to the ground in the fall. The lower portion of each stalk ("bine"), below ground, does not die, but forms an addition to the rootstock. The above ground stems are herbaceous, hollow and angular, and vary in color from pale green to purplish red or green streaked with purple. They have a twining habit, always winding about the support clockwise (Fig. 108). The angle of the support determines, to a degree, the manner and rate of growth. The most rapid and uniform growth is made, and the longest internodes produced, when the supports are vertical. The "bines" are assisted in their climbing and clinging to supports by the presence of hooked, retrorse

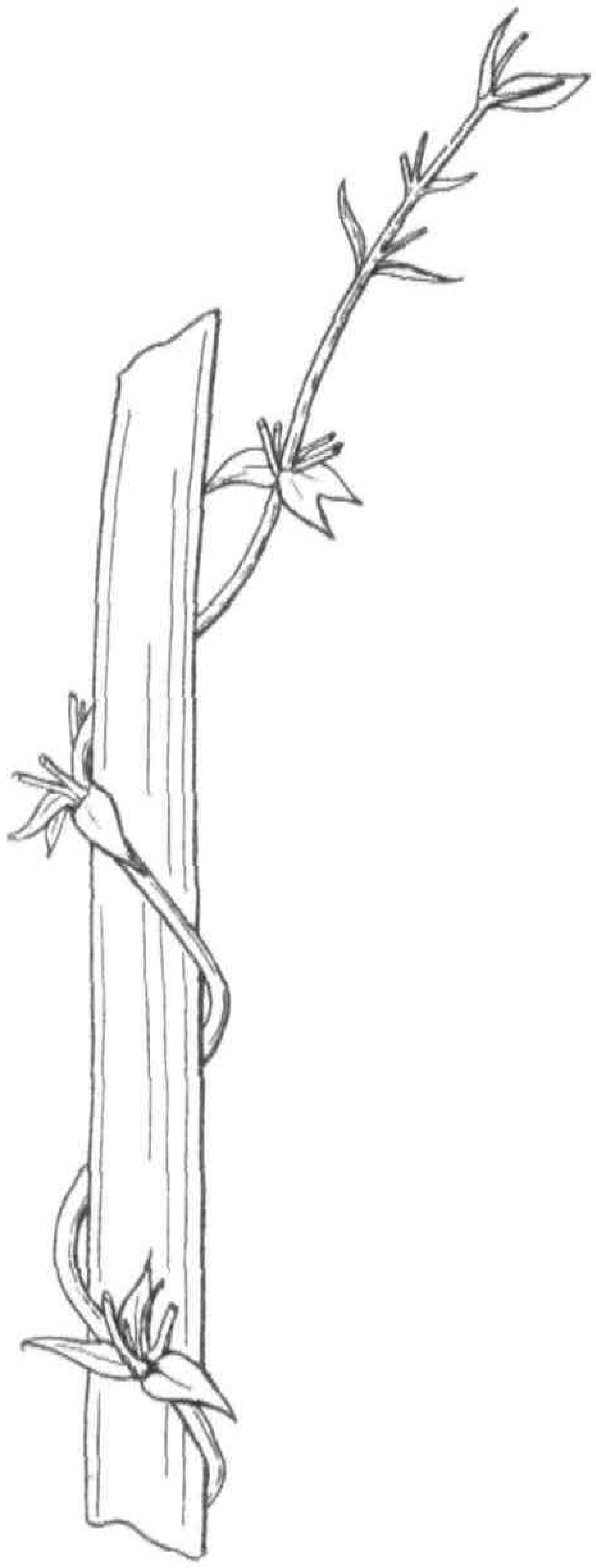


FIG. 108.—Dextrorse twining of hop stem.

hairs on each of the six edges of the stems, and on the petioles and leaf veins. The main stems bear opposite lateral branches. These reach their greatest length near the middle of the main stem. They bear the pistillate inflorescences (hops), and hence it is important that they be formed in abundance.

Leaves.—The hop leaves are opposite, broad, palmately veined, and three- to-five-toothed (Fig. 109). In palmately veined leaves there are several main veins which radiate from the leaf base. The stipules are broad, those of opposite leaves being united.

Inflorescences.—Hops are commonly diœcious, rarely monœcious. Hermaphroditism in hops has been noted. Some have held that injury is the cause of this abnormality. This theory has been refuted by Stockberger as a result of a number of experiments in which the plants were cut back, or pruned, or the tap root removed or portions of the crown removed. All of them failed to develop the abnormality (hermaphroditism). Hop plants of this type arise independently of injury. They transmit the abnormality to their progeny when propagated vegetatively. It is held that perfect flowers appear only in pistillate inflorescences.

Staminate inflorescences (Fig. 109, B) are paniculate, and grow from the axils of the main shoot or from the axils of lateral ones. *Pistillate inflorescences* (Fig. 109, A) are spike-like in appearance. They are the "hops" of commerce and are often spoken of as "burrs" or "strobiles." These are mostly borne in lateral branches from the main stem; they arise in the axils of the leaves.

The *pistillate inflorescence* has a central, hairy axis (Fig. 109, C) upon which are arranged a number of very short lateral branches or axes. At the base of each short lateral branch, or axis, is a pair of bract-like structures. These are in reality stipules belonging to leaves which, normally, do

not develop. Each of the lateral branches bears four pistillate flowers. Below each flower is a single bracteole

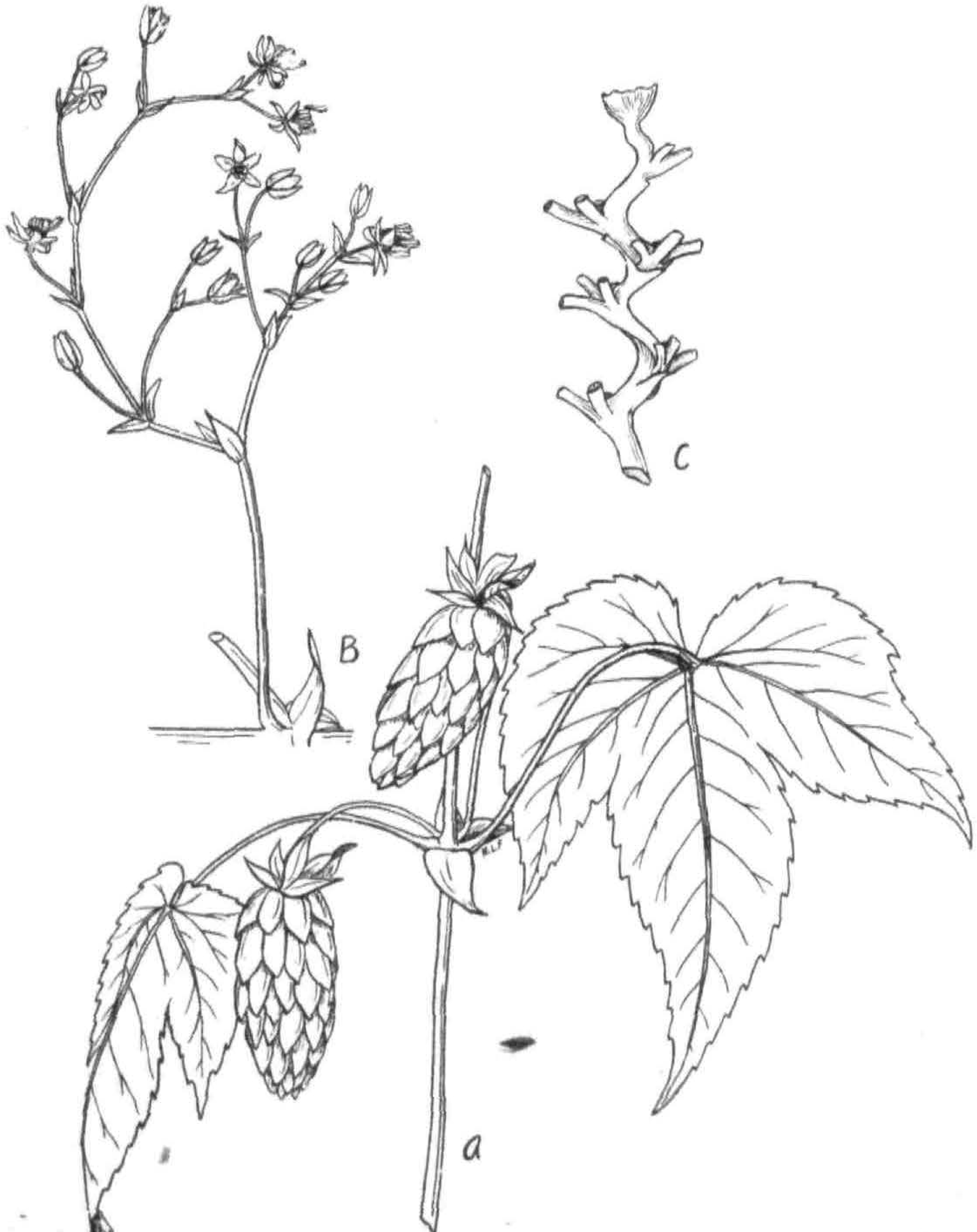


FIG. 109.—Hop (Humulus lupulus). *A*, portion of plant showing pistillate inflorescences; *B*, staminate inflorescence; *C*, rachis of pistillate inflorescence ("hop").

(small bract). Hence, examination of a single lateral axis or branch shows it to be made up of the following parts,

from below upwards: (1) two bract-like stipules; (2) bracteole and first flower; (3) bracteole and second flower; (4) bracteole and third flower; (5) bracteole and fourth flower.

Flowers.—The staminate flowers (Fig. 110, A) measure about 6 millimeters in diameter. They have a five-parted calyx, no corolla, and five stamens opposite the calyx lobes. Each pistillate flower (Fig. 110, B) is subtended by a single bracteole (Fig. 111, A) that partially encloses it at maturity.

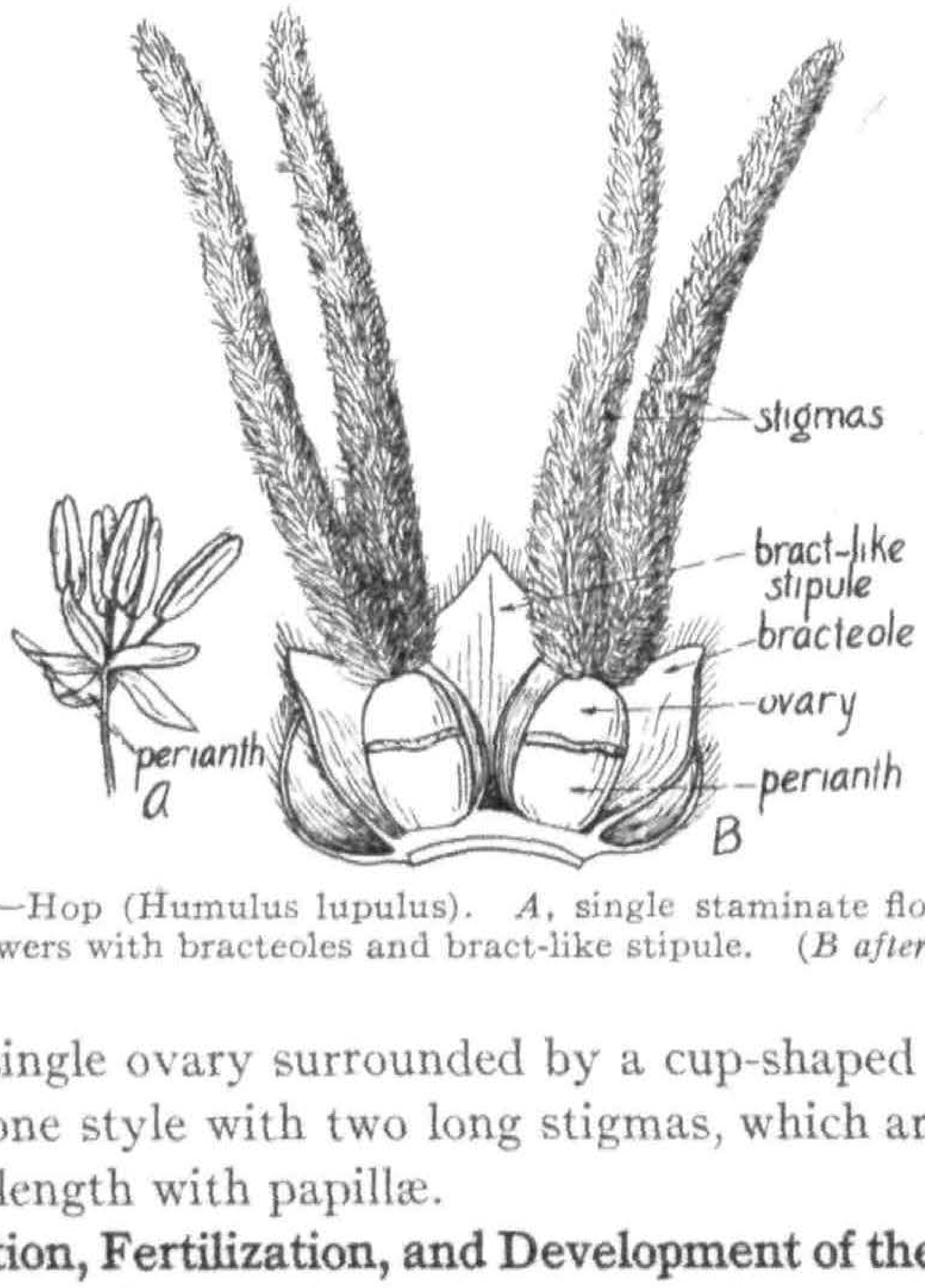


FIG. 110.—Hop (Humulus lupulus). *A*, single staminate flower; *B*, two pistillate flowers with bracteoles and bract-like stipule. (*B after Wossidlo.*)

It has a single ovary surrounded by a cup-shaped perianth. There is one style with two long stigmas, which are covered their full length with papillæ.

Pollination, Fertilization, and Development of the "Hops." The long, brush-like stigmas adapt the plant to wind pollination. When the pistillate inflorescences are young, the stigmas protrude from between the small "bracts" and become very conspicuous. Only the basal bracts of the inflorescence are to be seen. As soon as fertilization has

taken place the stigmas ("brush") drop off and the "bracts" rapidly increase in size.

The necessity for fertilization to secure the best development of the "hop" has been determined by a number of observers. The hops will only develop properly when a certain number of bracteoles bear seeds. If the young pistillate inflorescences ("burrs") are enclosed in paper bags to prevent fertilization, no seeds result, and the hops are poorly developed. It is true that the bracteoles develop to some extent without fertilization of the ovules, but the bracteoles connected with normal seeds are much larger and a brighter yellow than those bearing rudimentary seeds. Furthermore, hops, not fertilized, remain in blossom longer than those fertilized. Howard has shown that hops artificially pollinated start to grow out at once, while those not pollinated at all begin their growth seven to ten days later. He shows that fertilization stimulates growth, hastens ripening, improves the color and increases the mold-resisting power of the plant. It has been shown that, in England at least, seeded hops bearing an average of 9.5 seeds per hop, contained 15 per cent. resin and produced 147 pounds of resin per acre, while seedless hops contained 17.2 per cent. of resin and produced 92 pounds of resin per acre. It is true that there are certain disadvantages connected with growing seeded hops. Extra space is needed for growing staminate plants, and there is also a possibility that the soil is more quickly exhausted by seeded hops than by seedless ones.

The Mature Fruit.—The fruit (Fig. 111) is a small achene surrounded by the persistent cup-shaped perianth. The single seed within has a curved embryo about which is a small amount of endosperm.

Lupulin Glands.—In the mature hop, the outer surface of the bracteoles, the perianth, and, to a less extent, the bases

of the bract-like stipules are covered with yellow pollen-like grains, the so-called "hop-meal" or "lupulin" (Fig. 111).

Each yellow grain is a cup-shaped, multicellular, glandular hair filled with a resinous secretion. It is an outgrowth of an epidermal cell and consists of a short stalk and a cup of one layer of cells. Each cell has a rather thick cuticle. The secretion of the cells collects just beneath the cuticle, raising the latter up until finally the cup-shaped depression is filled with the secretion which remains covered by the cuticle itself. In immature hops, the lupulin glands are bright yellow and transparent. In mature hops, they are a paler yellow and somewhat opaque. The commercial value of hops depends entirely upon the amount and quality of the "hop-meal." It constitutes from 15 to 32 per cent. by weight of the hop.

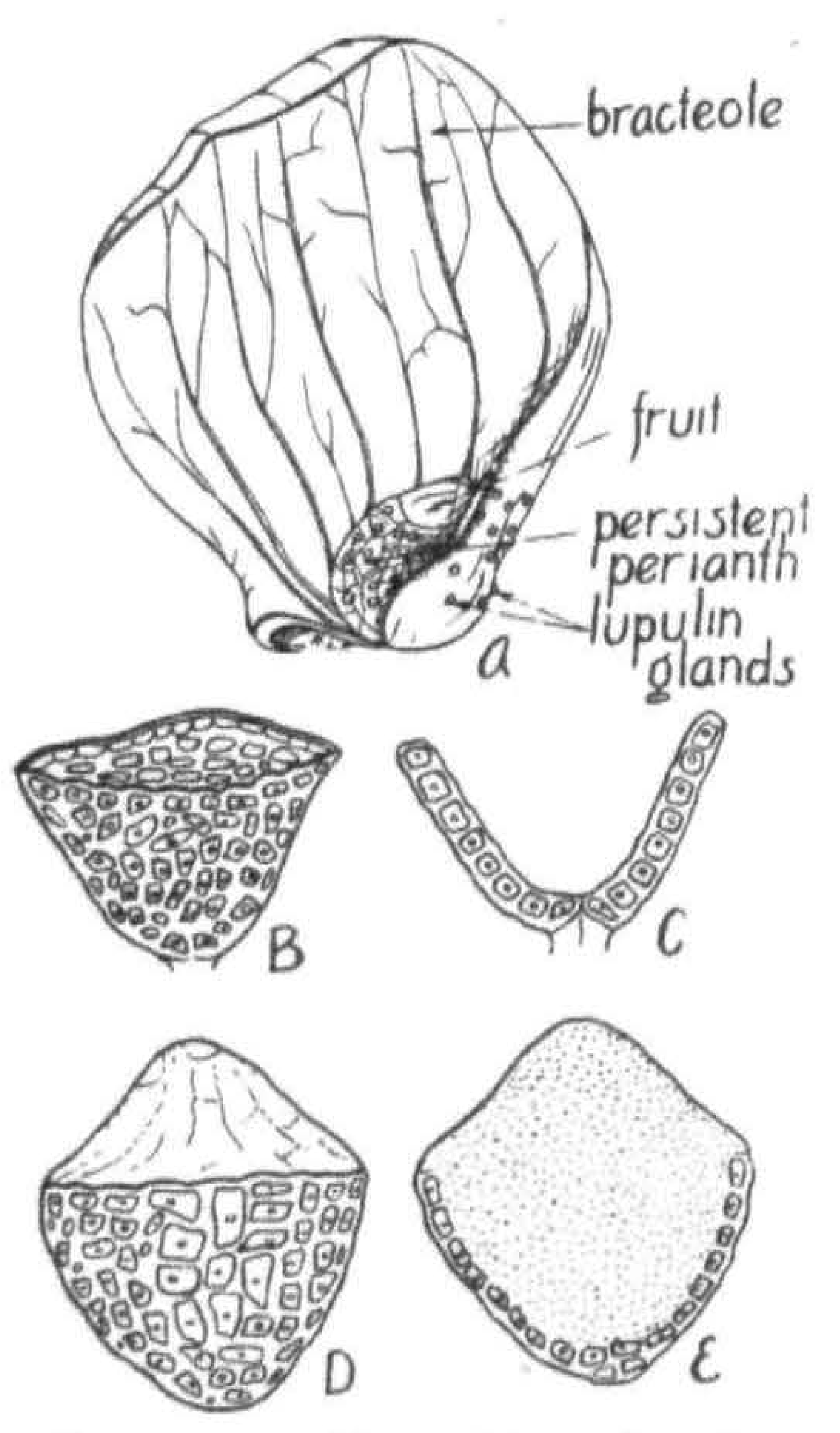


FIG. 111.—Hop (Humulus lupulus). *A*, bracteole; *B*, immature lupulin gland; *C*, same in section; *D*, mature lupulin gland; *E*, same in section. (*B–E after Percival.*)

Geographical.—The hop grows wild in England, the northern part of the continent of Europe and in Asia as far as eastern Siberia and south to Persia; it also grows wild in North America, across the continent westward to New Mexico and British America. It requires a moist, cool climate to attain its best development. Oregon, California, New York, and Washington are the leading States in the commercial production of hops.

Closely Related Species.—*Humulus japonicus*, the Japanese hop, is grown as an ornamental plant. It is an annual; its pistillate inflorescence does not enlarge into a "hop."

Along streams from Wyoming to Utah, New Mexico and Arizona, there is a hop (*Humulus lupulus neomexicanus*) which is distinguished from the Linnæan species by its more deeply divided leaves and more sharply acuminate bracts.

Varieties.—There are a number of varieties of hops, based upon length and color of vines, size, shape and color of hop, shape of bracteoles and stipular bracts, aroma, lupulin content and time of ripening. In California the chief variety is Large Gray American. Common New York varieties are English Cluster, Pompey, Humphrey Seedling and Canada.

Composition.—The composition of the strobiles or hops is of great importance, for they possess the valuable constituents of the plant, most of which reside in the lupulin glands. There are four principal active ingredients in the "lupulin," as follows:

1. Essential oil.
2. Non-resinous bitter principle.
3. Resins.
4. Tannin.

Hop oil is volatile and gives the hop its characteristic aroma. The amount of essential oil in hops varies from 0.2 to 0.8 per cent. The non-resinous bitter principle of the hop is probably the alkaloid, *lupuline*. Of the resins in the lupulin glands, two principal ones have been identified, a hard and a soft resin. The hard resin has a slight bitter taste and little or no antiseptic power in the beer wort. The soft resins are much more bitter, imparting this taste to the beer wort; they also prevent the growth of bacteria in the wort and thus have a preservative effect. The total resin content of hops varies from 10 to 18 per cent. Hop tannin makes up about 4 to 5 per cent. of the hop. It is thought by some that it serves to precipitate the albuminous material from beer wort.

Uses of Hops.—In some European localities, young hop sprouts are used as an early spring vegetable. The most tender sprouts are those which have been covered with soil during the winter.

Before the days of yeast cakes, yeast for bread-making was made by cultivating wild yeast in a decoction of hops and water. Some of the material obtained was mixed with the dough. The various constituents extracted from the hops add flavor to the bread, and also have antiseptic properties.

The most important use of hops, however, is in the brewing process. Preparatory to their use in the breweries, the hops are taken through a curing process in which they are kiln-dried, and then subjected to the fumes of burning sulphur. "Sulphuring" bleaches the hops, and acts as a preservative. After the sweet beer wort is made in the brewing process, it is boiled with hops. In this process, among other effects, the flavor of the wort is improved by the extraction of the active ingredients in the hops. The essential oil of the lupulin glands imparts an aroma to the beer, the non-resinous bitter principle and the resins give to the hopped wort a slightly bitter taste, and the tannin probably serves to precipitate albuminous substances. Moreover, the malic and citric acids in the hops tends to increase the acidity of the wort, and the ash adds to its mineral composition.

FICUS (Fig)

Habit, Roots, Stems.—Members of this genus are trees, shrubs or woody climbers (lianas). A number of species are parasitic on other trees. A parasite is an organism which secures its food material from another living organism. A complete parasite has no power of making its own food as do those plants which possess chlorophyll. The Golden Fig (*Ficus aurea*) begins life as an epiphyte; the seed germinates in the crevices of other trees; the aerial roots that are first

produced take root when they strike the soil, and hence become trunk-like. Aerial roots may be sent down from branches, take root and also form trunks. The banyan tree (*Ficus benghalensis*) also starts its life on the bough of a tree, receiving all its nutriment from substances available on the bark. Hence in its early life the banyan is an epiphyte. When once rooted in the soil, the plant becomes independent. In the East Indies, the banyan is "universally known as an immense living columned hall, consisting of a flat expanded

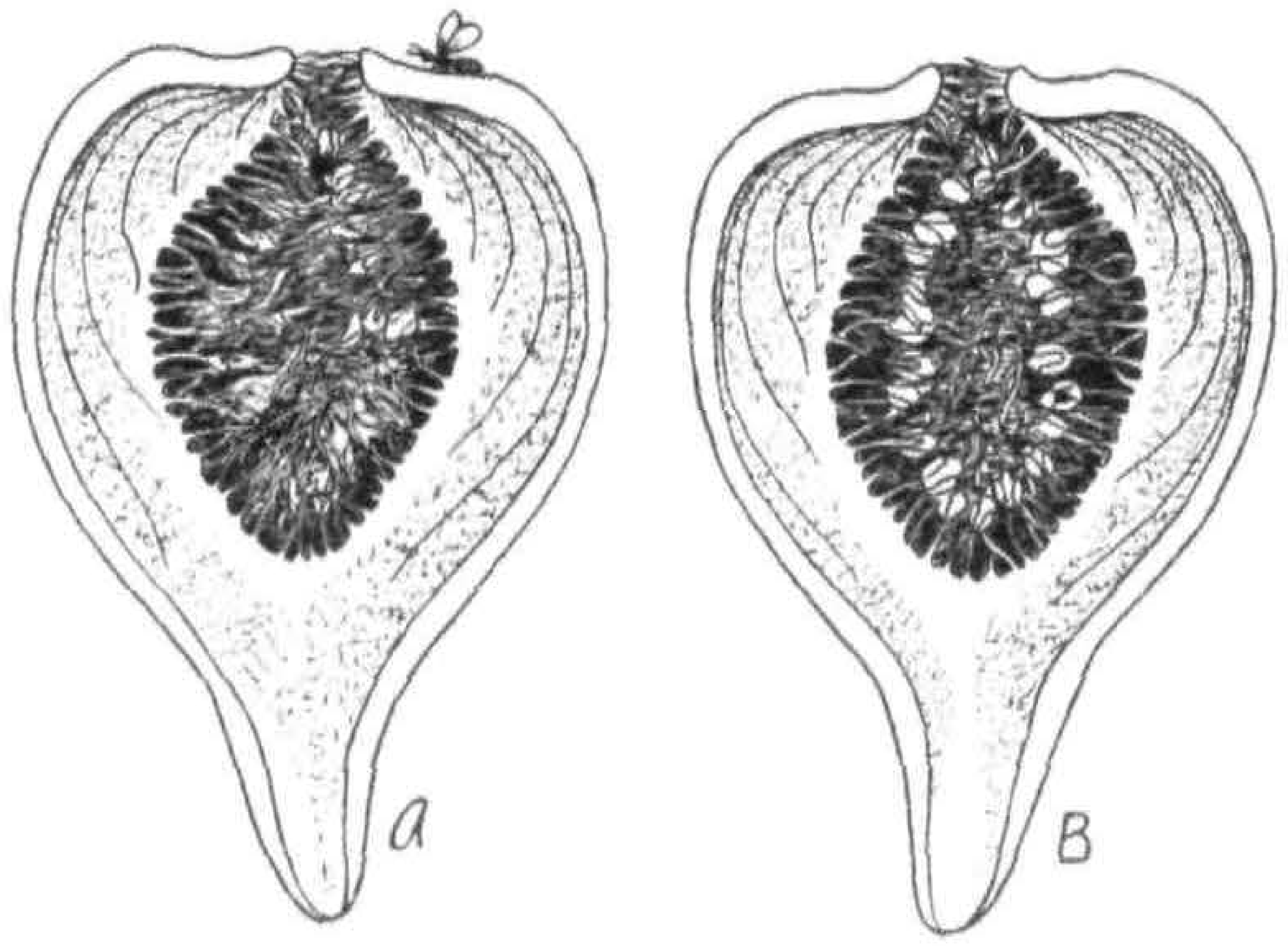


FIG. 112.—Pollination of the fig (Ficus carica). *A*, medium lengthwise section of a synconium containing fertile pistillate flowers; note the female fig wasp near the orifice, also another one which is inside. *B*, similar section of synconium showing gall flowers. (*After Kerner.*)

canopy of leaves and numerous stem-like prop roots growing down from the boughs" (Schimper's Plant Geography).

Leaves.—The *leaves* are alternate, sometimes opposite, thick, leathery and deciduous or persistent. In the Buddhists' sacred Peepul tree (*Ficus religiosa*), a plant of tropical rain forests, the leaves have a long "dripping point," by means of which rain water is soon drained off. The stipules are interpetiolar and early deciduous.

Inflorescence.—The *flowers* occur within an enlarged, fleshy, hollow receptacle (Fig. 112) which is commonly borne in the axils of leaves. Staminate and pistillate flowers may

be borne in the same receptacle or in different receptacles. Some tropical figs are cauliflorus, that is, the receptacle with its numerous small flowers is borne on main stems or branches. This is a rather unusual condition; in our common woody plants, the flowers and fruit are borne on young twigs only.

Staminate flowers have a two- to six-parted perianth (sometimes none), and one to three stamens with united filaments. In the staminate flowers, there is no indication of an ovary. *Pistillate flowers* have a two- to six-parted perianth (sometimes none), a single one-celled ovary and single style. The small nutlets are enclosed in the thick, succulent receptacle, forming a fruit known as a *synconium* ("fig").

Geographical Distribution, and Economic Importance.—There are about 600 species of the genus *Ficus* very widely distributed throughout the American tropics, southern Asia and the islands of the Pacific. Two species, *F. aurea* and *F. brevifolia*, are native to peninsular Florida and the Keys, while *F. carica* has been introduced into southern California and a number of Gulf States. As compared with other genera in the family Moraceæ, *Ficus* is by far of the greatest economic importance. The most important species is *Ficus carica*, the common fig of commerce.

FICUS CARICA (Common Fig)

Habit of Plant, and Stem.—The common fig is a shrub or small tree, seldom reaching a height of more than 25 feet. The main trunk of the tree is short. It branches rather irregularly, forming a round head. The gray or reddish bark is smooth and fits closely to the wood. The twigs are stout and thick, at first somewhat hairy but later becoming smooth and grayish-green in color. The fig is propagated mainly from stem cuttings.

Leaves.—These are thick and leathery and from 5 to 15 centimeters long. The general outline of the leaf is usually oval, sometimes about circular. The leaf base is truncate or slightly heart-shaped. There are five to seven deep lobes, which are coarsely toothed or slightly lobed again; each lobe is blunt at the tip. The leaves are light green, rough and hairy on the upper side, paler and hairy on the under side; leaf venation is prominent.

Inflorescence, and Flowers.—The numerous small flowers line the inner wall of a hollow receptacle (Fig. 112), except near the small opening ("eye") at the apex where there are scales or small leaves.

Among the various types of *Ficus carica*, there are four distinct kinds of flowers, staminate, pistillate, gall and mule.

Staminate Flowers (Fig. 113, E).—These rarely occur in cultivated figs, being found for the most part in the wild fig (Caprifig). They occur just below the scales in the receptacle. Each staminate flower usually has a four-lobed perianth which is shorter than the stamens. The stamens vary from one to five; four is the ordinary number.

Pistillate Flowers (Fig. 113, D).—Pistillate flowers are sometimes found in the Common Mission figs; they are the only sort in Smyrna figs; they also occur in the second crop of San Pedro figs, the first crop of Adriatic figs, the second crop of Erinocyce figs and the second crop (mammoni) of Caprifigs. In the receptacle of the latter, they come below the staminate flowers. The pistillate flowers have a three- to five-lobed perianth, which is rather fleshy. The single, superior ovary bears a bent style several times longer than the ovary, and often divided into two unequal stigmatic lobes.

Gall Flowers (Fig. 113, H).—These are found only in Caprifigs and Erinocyce figs. They are degenerate or transformed pistillate flowers, not producing seed; the ovary harbors the eggs and larvæ of the fig wasp (Blastophaga). It must

not be thought that gall flowers are true pistillate flowers modified by the fig wasp; they exist independent of the wasp; the wasps select them for the deposit of their eggs. Gall

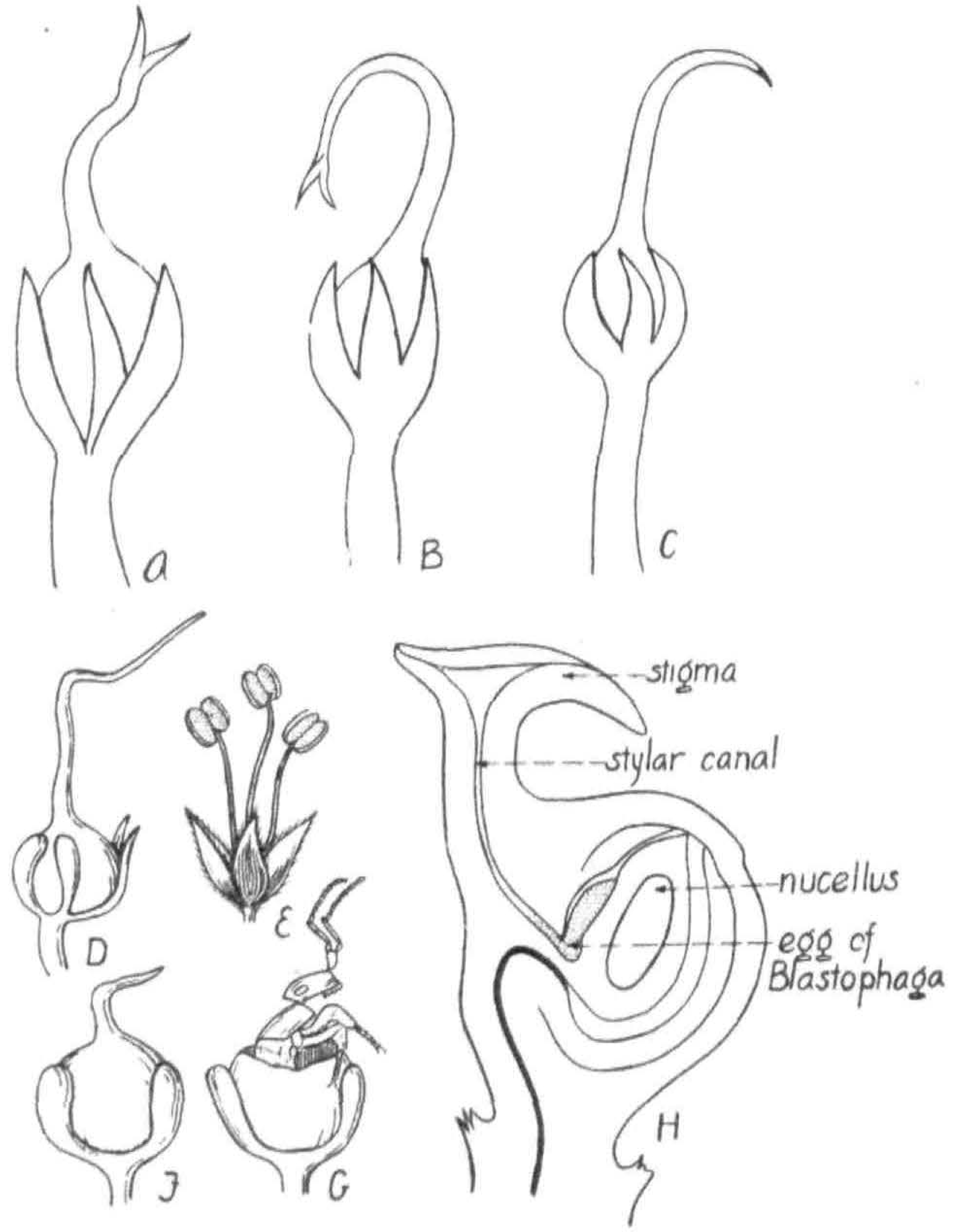


FIG. 113.—Flowers of fig (Ficus carica). *A*, *B* and *C*, mule flowers; *D*, long-styled pistillate flower; *E*, staminate flower; *F*, gall produced from a short-styled gall flower; *G*, fig wasp escaping from a gall; *H*, gall flower. (*A*, *B*, *and C after Eisen; D to G after Kerner; H after Solms-Laubach.*)

flowers occur at the base of the receptacle. Their perianth is smaller than that in true pistillate flowers; the style is very short or entirely wanting; the embryo is imperfect and the stigmas do not possess receptive papillæ.

Mule Flowers (Fig. 113, A, B, C).—With the exception of an occasional pistillate flower, mule flowers are the only kind found in the common edible fig. They are also the only sort present in the first crop of San Pedro figs, and second crop of Adriatic figs. They are not present in Caprifigs. They are imperfect pistillate flowers neither capable of maturing seed nor serving as a breeding place for the fig wasp. The style is intermediate in length between that of gall and of true pistillate flowers; the stigmas are non-receptive; the embryo is imperfect, and hence no seed is produced.

Pollination.—The common edible fig comes to maturity without pollination, artificial or otherwise. In other types of figs all or at least one of the crops require the visitation of the fig wasp (*Blastophaga psenes*) in order that the fruit form properly. The close dependence of certain figs upon this insect has been a topic of great interest to students of botany. Pollination in the Caprifig will be considered first.

Crops of Fruit in Caprifigs.—In the wild fig (Caprifig) there are three crops of fruit in a year. These are as follows:

First Crop (Profichi).—The figs of this crop form in the autumn, rest over the winter and mature the following June or July. They bear staminate and gall flowers but no pistillate flowers. When the figs are about one-fourth grown, female wasps enter and deposit their eggs in the gall flowers. In about two months, the eggs hatch out, the perfect wasps emerge and the females, covered with pollen, come from the fig and seek other figs in which to deposit their eggs. By this time (June and July) the second crop of figs is about one-fourth grown.

Second Crop (Mammoni).—The fruits of this crop possess staminate, pistillate and gall flowers. The wasps which emerge from the figs of the first crop enter the narrow orifice at the apex of the receptacle (second crop), crawl down along the inner side, first over the staminate flowers, then over

the pistillate flowers, finally reaching the gall flowers at the base of the receptacle, in which they deposit the eggs. The pollen on their bodies is rubbed off on the receptive stigmas, which are elevated on the long, curved style, and thus pollination is secured. As a result, a few fully developed seeds are found in the second crop of Caprifigs. In August or September the eggs, deposited in the gall flowers of the second crop, hatch out. The mature female wasps emerge from the receptacle, in search of other figs in which to lay their eggs. By this time the third crop of Caprifigs is about one-fourth grown.

Third Crop (Mamme).—The figs of this crop possess staminate and gall, but no female flowers. When they are about one-fourth grown, August or September, wasps from the second crop come to them, depositing eggs in the gall flowers. These figs, together with the eggs of the wasp, hibernate until March or April, when the perfect insects hatch out, seeking the profichi stage. Only those figs which harbor *Blastophagas* remain on the tree.

Caprification.—It will be recalled that the common edible fig matures its fruit without fertilization. Such is not the case with some other types, particularly Smyrna figs. The latter have only pistillate flowers and, unless these are fertilized, the receptacle does not come to full maturity. Hence, it has been found necessary, in order to grow Smyrna figs, to resort to artificial fertilization.

The artificial process of fertilization as applied to figs is termed caprification. In this horticultural process, a number of first-crop figs (profichi) of the Caprifig are suspended on the branches of the Smyrna tree. The female Blastophagas which hatch from the eggs in the gall flowers of the profichi become covered with pollen as they emerge from the figs. In search of a place to lay their eggs, they go to the partly mature figs of Smyrna. They enter the

orifice of the fig and scatter pollen on the stigmas, and fertilization of the ovules ensues. The pistillate flowers of the Smyrna fig, unlike the gall flowers, have styles of such a length that the wasps are unable to lay their eggs in the proper place. Consequently, the wasps perish in the fruit and their bodies are absorbed by the growing cells. Gall flowers are the only ones in which eggs may be laid properly, and hatch.

In California, caprification of Smyrna figs is done in June or July. The second crop of San Pedro figs and the first crop, but not the second, of Adriatic figs, require caprification.

Effects of Fertilization (*Caprification*).—In caprifigs, as has been noted, there are two general types of receptacles: those possessing pistillate flowers (mammoni) and those without pistillate flowers (profichi and mamme). The effects of fertilization may be observed in comparing the behavior of caprificated figs of the mammoni with the non-caprificated ones of the profichi and mamme, or the non-caprificated ones of the mammoni.

Prior to fertilization, the figs of the two types are about the same size. Caprificated figs become larger than those not fertilized; they cling to the tree more tightly, the ribs are more pronounced and the branches that bear them grow more vigorously.

As has been indicated, Smyrna figs must be caprificated to bring about the development of the ovaries and seeds and the proper ripening of the receptacle. The superiority of Smyrna figs is due to the aromatic flavor of the seeds.

The Mature Fruit.—The "fruit" of fig (Fig. 112) is termed a synconium. This is a pear-shaped receptacle on a very short stalk; the nutlets (true fruits), when present, are imbedded on the inside of the fleshy receptacle walls. At the apex of the fig, is the "eye" or orifice of the receptacle.

The "neck" and "cheeks" (sides) of the fruit are marked by a number of rings. The fruits vary widely as to size, form, neck, stalk, ribs, eye, color of skin, color of pulp, seeds, quality and growth.

Geographical.—*Ficus carica* is considered to be a native of southern Arabia. Some one or more of its different types are now grown in most of the tropical and subtropical countries. The first figs brought into the United States were a common edible type and were introduced into California by the Franciscan order of Mission Fathers. From California, they have spread and are now being cultivated in many of the Southern States. Fig culture in the cooler sections of the United States is very limited, and special care needs to be taken there to prevent the trees from winter-killing.

Closely Related Species in the United States.—In Florida, there are two native figs (*F. aurea and F. brevifolia*) which are distinguished from the common figs by their entire, smooth leaves, and small, inedible fruit.

Types of Figs.—Eisen describes the following types of figs:

1. *Common Figs* or *Mission Figs.*—These produce two crops of fruit without caprification or fertilization. Mule and a few pistillate flowers are present, but there are no gall or staminate flowers, except in a very few cases. The figs of the first crop occur on old wood. First crop figs are called "Brebas." Second-crop fruit is borne in the axils of current leaf growth, on new wood. Second-crop figs are called "Summer figs." Brebas are large figs, not very rich in sugar, and are desirable for eating fresh. Summer figs are smaller and sweeter, and hence are suitable for drying.

2. *Smyrna Figs* (known in California as "Bulletin Smyrnas" or "Lobfigs").—These bear only pistillate flowers and produce fruit only when caprificated or hand-pollinated. The seeds produced are perfect, and it is the aromatic qualities in them to which the superiority of Smyrna figs is due. Smyrna figs are no w grown with success in California.

3. *San Pedro Figs.*—First crops figs of this group bear mule flowers only, and the fruit matures without the necessity of caprification. The second crop of figs produces only pistillate flowers and these must be fertilized, if the fruit is to reach maturity.

4. *Adriatic Figs.*—This is a type of fig in which the Brebas require caprification, while the second crop does not.

5. *Erinocyce Figs.*—This is a rare type in which the first crop is inedible, producing staminate and gall flowers, while the second crop has both pistillate and gall flowers.

6. *Cordelia Figs.*—These are also rare. They are an edible fig possessing only staminate flowers.

7. *Caprifigs.*—This is considered to be the original type of fig from which all the above have come. They grow wild in southern Europe, northern Africa and western Asia. There are three crops of Caprifigs: *First crop* (*profichi*), which bear staminate and gall flowers, but not pistillate. The receptacles form in the autumn, maturing the following June or July. *Second crop* (*mammoni*); staminate, pistillate and gall flowers occur in the figs of this crop. The fruit matures in August or September. *Third crop* (*mamme*); the figs of this crop have only staminate and gall flowers. They hibernate over the winter, reaching maturity in March or April.

Uses of Figs.—Figs are grown chiefly for the fruit. This is sometimes eaten fresh, but is more commonly dried for transportation. Brebas are juicier than Summer figs, and hence are more desirable for eating raw. Summer figs and Smyrnas, however, are richer in sugar, and for this reason are better for drying. A limited area of land near Smyrna produces the largest percentage of dried figs. However, the industry of drying figs is growing in California. Here, the figs are washed in salt water, dried, and rewashed in salt water, graded, and packed. Fig syrup is a medicinal

product of the fruit. The fig tree is sometimes planted for ornament and shade, and the soft, light, but elastic wood finds considerable use.

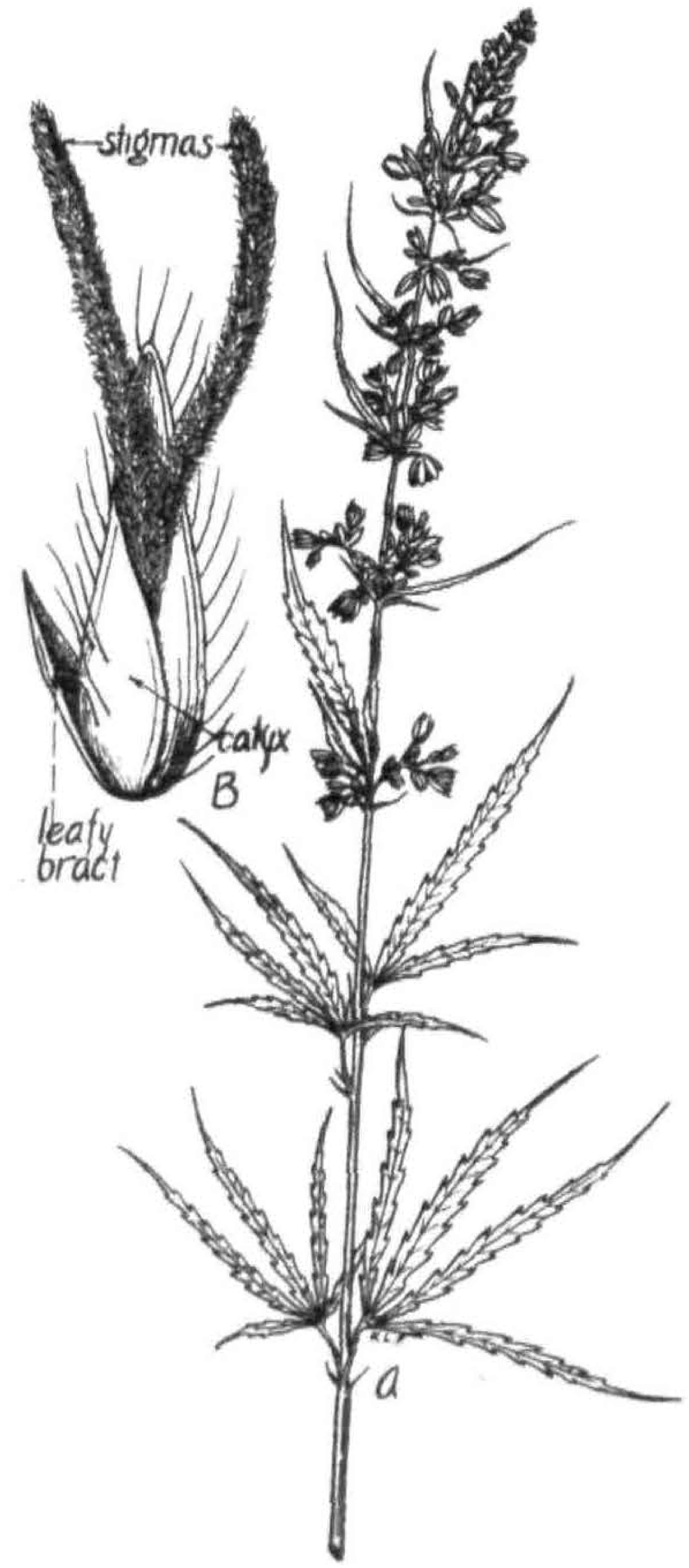


FIG. 114.—Hemp (Cannabis sativa). *A*, branch of staminate plant; *B*, single pistillate flower. (*B after Wossidlo.*)

CANNABIS SATIVA (Hemp)[1]

Description.—The common hemp is a stout, erect, branching annual, 5 to 15 feet high. The main *stem* is hollow and produces a few branches near the top. The *leaves* are alternate above and opposite below. They are compound, digitate, with five to eleven linear-lanceolate, pointed and serrate leaflets. Hemp is diœcious. The *staminate inflorescences* (Fig. 114, A) are in axillary, narrow and loose panicles, the *pistillate* in erect, leafy spikes, also axillary. The *staminate* flower is borne on a slender pedicel subtended by a

[1] Unfortunately, the name "hemp," has come to be applied to the fiber of a number of different plants, which has led to some confusion. For example, abaca is called "Manila hemp," sisal is called "sisal hemp," henequen, "Mauritius hemp," jute "Calcutta hemp," and *Phormium* is called "New Zealand hemp." It should be understood that but one species of plant, namely *Cannabis sativa*, is correctly called "hemp," and the fiber of which is known as "hemp."

bracteole; it has five distinct sepals and five short stamens. Each *pistillate* flower (Fig. 114, B) is subtended by a leafy bract, and possesses a single, thin, entire calyx segment, wrapped about the ovary. The *ovary* has two thread-like feathery stigmas. Hemp is wind-pollinated. The ovary matures into an ovoid, hard achene. The curved embryo is imbedded in a fleshy endosperm. The fruits of hemp are much larger and heavier when grown in a moist habitat than when grown in a dry one.

Geographical.—The native home of common hemp is central and western Asia. It has spread, as a result of cultivation, throughout Europe, Asia and America. In many places, it has escaped from cultivation and become a rather troublesome weed.

Varieties.—Nearly all hemp grown in this country is of Chinese origin. The Japanese hemp is identical, or very similar, to Chinese hemp. European varieties (Piedmont, Neapolitan, Hungarian, and Russian), often termed Smyrna types, differ from the Chinese and Japanese ones in that the plants are shorter, the growth is more compact, the seeds are in denser clusters and earlier in maturing. The best quality of hemp fiber comes from Italy.

The Hemp Industry in the United States.—Since about the year 1906, there has been a slight decline in the domestic production of hemp. This falling off has been due to the difficulty of obtaining laborers to do the work of retting, breaking, and preparing the fibers for the market; to the lack of development of labor-saving machinery; to the fact that greater profits are derived from raising other crops in hemp-growing regions; and to the greater use of other fibers in the manufacture of products formerly made of hemp.

Kentucky began to raise hemp in 1775, and that State now leads in hemp production. Kentucky now furnishes the seed for nearly all of the hemp grown for fibers in the United

States; the hemp from this State is mostly of Chinese origin. The chief hemp-growing States are Kentucky, California, Nebraska, Indiana, New York, and Wisconsin.

Preparation of Hemp for Market.—*Harvesting Hemp.*—In some places, hemp is still harvested by hand with a reaping knife or hemp hook. However, in most hemp-growing districts, sweep-rake reapers, mowing machines, or self-rake reapers are used.

Ky. Agricultural Experiment Station

FIG. 115.—Cutting hemp, Kentucky. (*From Essentials of Geography, Second Book. Copyright, 1916, by Albert Perry Brigham and Charles T. McFarlane., American Book Company, Publishers.*)

The hemp stalks, usually 5 to 12 feet long, are bound into bundles about 10 inches in diameter, and shocked. They are allowed to stand in the shocks for ten to fifteen days, or until they are dry enough to be stacked.

There is an advantage in stacking hemp, in that it rets more quickly and more uniformly than hemp that is taken directly from the shock. Furthermore, the stacking of hemp improves the quality and yield of the fiber.

Retting.—This is a process in which the substances surrounding the bast fibers are partially dissolved, thus allowing the fibers to be separated from the wood ("hurd") and thin outer bark, and from each other. This separation is due to the decomposing action of certain bacteria and fungi. There are two commercial methods of retting: *dew-retting* and *water-retting*. The former is the common method in this country. The hemp stalks are spread out in thin, even rows on the ground, where they are exposed to alternate freezing and thawing, or to cool, moist weather. The process of retting is complete when the bark separates easily from the woody portion ("hurd") of the stem. Water-retting is practised in European and Asiatic countries. The stalks are immersed in streams, ponds, or artificial tanks.

Breaking.—In the breaking process, the inner cylinder of wood is broken in pieces, which permits it to be removed, leaving behind the long bast or hemp fibers. The removal of the broken pieces of woody tissue is known as *scutching*. In this country, both hand breaks and machine breaks are in use. The stems must be dry before breaking, so that the woody core can be satisfactorily crushed and the fiber properly cleaned.

Hackling.—The long, straight hemp, known as ***rough hemp***, is sorted and hackled by hand. In the process of hackling, the rough fiber is combed out by drawing it over coarse hackles; the product is known as "*single-dressed hemp*." This may be combed out by drawing it over finer hackles, thus preparing a fiber known as "*double-dressed hemp*." Double-dressed hemp brings the better price on the market. *Hemp tow* is "any more or less tangled strands of fiber which are removed from the straight hemp in preparing it for market or for spinning."

Uses of Hemp.—Hemp is grown primarily for its fiber. The fibers are in the bast and average about 20 millimeters

in length. They are of the best quality if the plants are cut when staminate plants are in full bloom. If cut too early, the fibers lack strength, and if harvested too late they are coarse and brittle.

Hemp fiber is put to a variety of uses. It is used in the manufacture of sail cloth, yacht cordage, binder twine, tying twine, carpet yarns, carpet thread, sacking, bagging, rope, upholstery webbing, and belt webbing. The ravelings of hemp rope, termed "oakum," are used for calking seams of wooden boats and joints of iron pipe, in pumps, engines, and other machinery. The seed of hemp is often fed to poultry and cage-birds. Moreover, the seed contains 20 to 25 per cent. of an oil, which is sometimes extracted and used as a substitute for linseed oil. The drug *Cannabis indica* is derived from the stems and leaves of common hemp, which under the hot climatic conditions of India, chiefly, develop a volatile oil and a strong narcotic resin (cannabin). These substances are secreted by the glandular hairs on stems and leaves. It has recently been shown that as good quality of the drug, cannabin, can be obtained from hemp grown in Wisconsin and other northern states as can be secured from plants grown in warmer sections. This is contrary to the generally accepted opinion. Hemp-seed oil is used for making soft soaps, as a paint oil, and low grades are utilized for certain varnishes. Recent tests show that a fair quality of paper can be made from hemp "hurds."

The chief fiber competing with hemp is jute. Jute is produced in India from two species of plants, *Corchorus capsularis* and *Corchorus olitorius*. It is used extensively for the manufacture of sugar sacks, gunny sacks, burlaps, grain sacks, and wool sacking. It is about two-thirds as strong as hemp fiber of the same weight, and is not as durable. Although hemp has been used to some extent in the manufacture of binder twine, most of the binder twine now is made from the fibers of sisal and abacá.

References

BAILEY, L. H.: Mulberries. Cornell Agr. Exp. Sta. Bull. 41: 223–243, 1892. Sketch of the Evolution of Our Native Fruits. The Macmillan Co., 1898.

BRIANT, LAWRENCE, and MEACHAM, C. S.: Hops. The Influence of Climate, Ripeness, Soil, Drying, and General Manipulation on the Value of Hops. Jour. Fed. Ins. Brewing, 2: 423, 1896.

CHAPMAN, A. C.: The Essential Oil of Hops. Proc. Chem. Soc. (London), 9: 177, 1893; 10: 227–229, 1894. Jour. Chem. Soc. (London), Trans., 67: 54–63, 1895. Jour. Fed. Inst. Brewing, 4: 224–233, 1898. Jour. Chem. Soc. (London) Trans., 83: 505–513, 1903.

The Hop and its Constituents. A Monograph on the Hop Plant. London, 1905. Published by Brewing Trade Review.

CHEDSEY, M.: The Influence of Pollination upon the Development of the Hop (*Humulus lupulus*). Plant World, 8: 281–283, 1905.

CONDIT, I. J. Caprifigs and Caprification. Calif. Agr. Exp. Sta. Bull. 319: 341–377, 1922.

COOK, O. F.: Sexual Inequality in Hemp. Jour. Hered., 5: 203–206, 1914.

EISEN, GUSTAV: Edible Figs, their Culture and Curing. U. S. Dept. Agr. Div. Pom. Bull. 5: 1–33, 1897.

The Fig: Its History, Culture, and Curing. U. S. Dept. Agr. Div. Pom. Bull. 9: 1–317, 1901.

Biological Studies on Figs, Caprifigs, and Caprification. Proc. Cal. Acad. Sci., ser. 2, vol. 5: 897–1003, 1896.

GROSS, E.: Hops in Their Botanical, Agricultural, and Technical Aspects and as an Article of Commerce. Scott, Greenwood & Co., London, 1900. Transl. from German by C. Salter.

HOWARD, A.: Hop Experiments in 1904. Councils Kent and Surrey. South-eastern Agr. Col., Wye, Bull. 1: 1–29, 1904–5.

The Influence of Pollination on the Development of the Hop. Jour. Agr. Sci., 1: 49–58, 1905.

HOWARD, L. O.: The Present Status of the Caprifig Experiments in California. U. S. Dept. Agr. Div. Ent. Bull. 20 (new ser.): 28–35, 1899.

Smyrna Fig Culture in the United States. U. S. Dept. Agr. Yearb., 1900: 76-106, 1901.

MATTHEWS, J. M.: The Textile Fibers: Their Physical, Microscopical, and Chemical Properties. John Wiley & Sons, 1911.

MYRICK, H.: The Hop: Its Culture and Curing, Marketing, Manufacture. Orange Judd Co., 1899.

POWER, F. B., TUTIN, F., and ROGERSON, H.: The Constituents of Hops. Jour. Chem. Soc. (London), 103: 1267–1292, 1913.

RABAK, F.: Aroma of Hops: A Study of the Volatile Oil with Relation to the Geographical Sources of the Hops. U. S. Dept. Agr. Jour. Agr. Research, 2: 115–159, 1914.

SALMON, E. S., and AMOS, A.: On the Value of the Male Hop. Jour. Southeast. Agr. Col., Wye, 17: 365–391, 1908.

SALMON, E. S.: The Pollination and Fertilization of Hops and the Characteristics of "Seeded" and "Seedless" Hops. Jour. Agr., 21: 22–31, 123–133, 1914.

SCHMIDT, J.: Investigations on Hops, V. On the Aroma of Hops. Compt. Rend. Lab. Carlsberg, 11: 149–163, 1915.

STOCKBERGER, W. W.: Change of Sex in Humulus Lupulus not Due to Traumatism. Abs. in Sci., n.s. 31: 632, 1910.

TOURNOIS, J.: Sexual Studies of the Hop Plant. Ann. Aci. Nat. Bot., 9 ser., 19: 49–191, 1914.

WINGE, O.: The Pollination and Fertilization Processes in Humulus Lupulus L. and H. Japonicus Sieb, et Zucc. Comp. Rend. Lab. Carlsberg, 11: 1–46, 1914.

CHAPTER XXII

POLYGONACEÆ (Buckwheat Family)

Herbaceous representatives of this family are largely found in temperate regions, tree-like species in American tropics, while shrubby ones are limited to western Asia. There are about 30 genera and 800 species. Rhubarb and buckwheat are the principal cultivated members, while a number of species of *Rumex* (dock), and of *Polygonum* (knot-weed, bind-weed, etc.) are bad weeds.

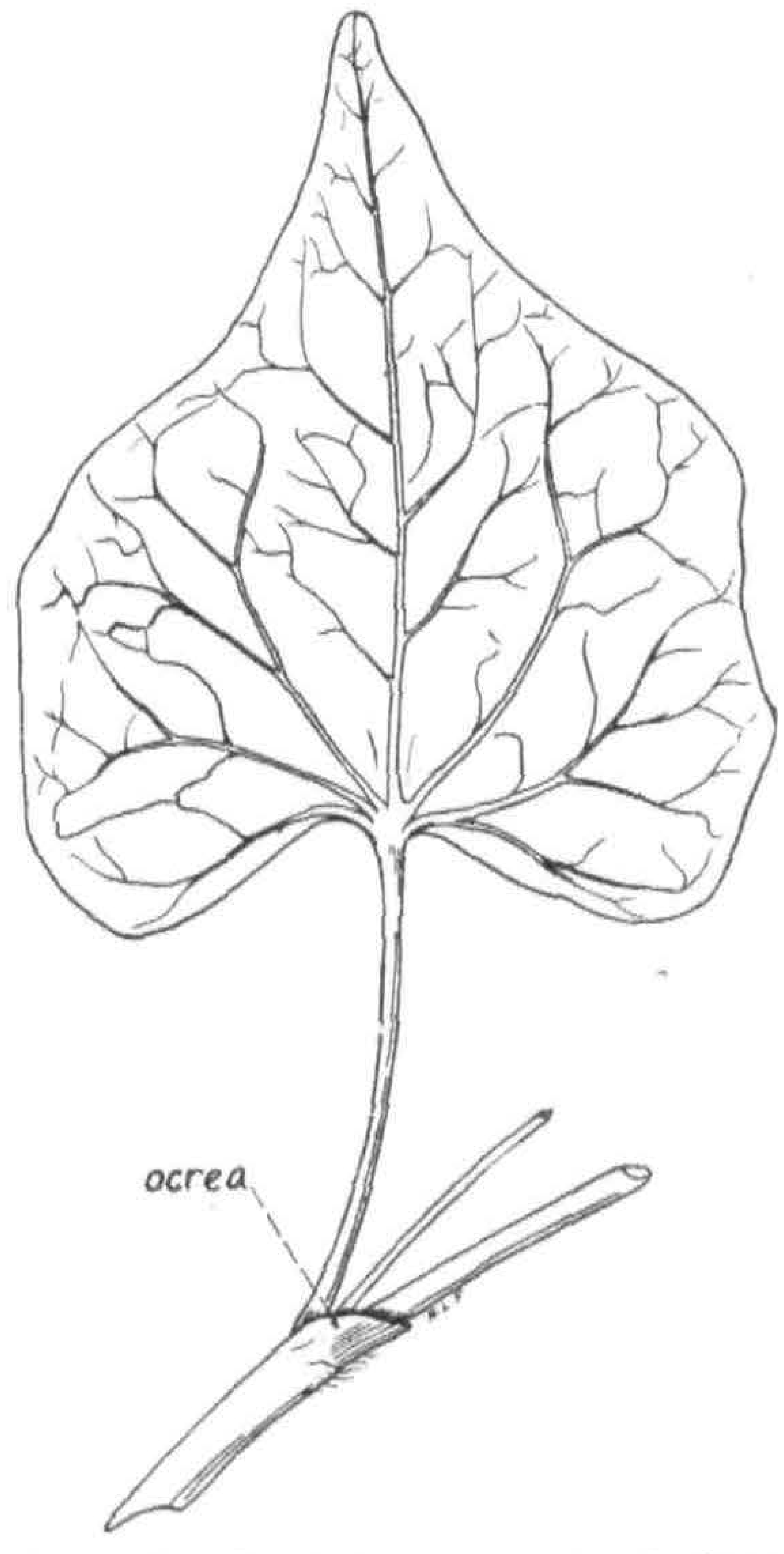


FIG. 116.—Leaf of common buckwheat (Fagopyrum vulgare). × 1.

Stems and Leaves.—The *stems* are conspicuously jointed and usually swollen at the joints. The *leaves* are alternate (*Fagopyrum*), opposite (*Macounastrum*), or whorled (mountain sorrel, *Oxyria digyna*). They are mostly entire, rarely lobed or divided. The stipules, with a few exceptions, are membranous, sheathing, and united to form a very characteristic structure, the *ocrea* (plu. ocreæ) (Fig. 116).

Inflorescences.—The *inflorescences* vary a great deal within the family; in buckwheat they are panicled racemes, in *Polygonum* spp., terminal or axillary spike-like racemes, in *Eriogonum* spp., cymes, umbels or heads. The cyme is a determinate type of inflorescence. In this type, the terminal flower is the oldest and subsequent ones open in order from the inside to the outside of the inflorescence (centrifugal opening of the inflorescence). The umbel type of inflorescence has been described on page 231 in the onion. In the head type of inflorescence, so well exemplified by the dandelion or sunflower, the flowers are crowded on the receptacle and the stalk of each flower is very short or entirely absent; it is an indeterminate type.

Flowers.—The flowers are small, mostly perfect, rarely diœcious or monœcious, and radially symmetrical. In the genus *Eriogonum*, the flowers are subtended by a five- to eight-toothed involucre. The *calyx* consists of two to six segments which are below the ovary and free from it; the segments are in one or two series, often imbricated (overlapping), and the inner or both series are petaloid (resembling petals). There are no *petals*. The *stamens* vary from two to nine; in perfect flowers, they are attached near the base of the calyx, while in staminate ones, they may be crowded on a central disk; the filaments are filiform, mostly distinct but sometimes united in a ring at the base, and commonly dilated at the base; the anthers possess two cells, and are longitudinally dehiscent. The *pistil* is solitary. The superior *ovary* is one-celled, three-angled or compressed, rarely four-angled, and usually sessile; the styles are most frequently three in number, rarely two or four, and attached to the apex of the ovary; the stigmas are capitate (head-shaped) or tufted, and sometimes two-cleft. Within each ovary there is a single ovule.

Fruit.—The *fruit* is a three-angled (rarely four-angled) achene, about which is frequently the persistent calyx; the pericarp is hard or leathery. The single seed in each fruit assumes the shape of the pericarp; the seed coat (testa) is membranaceous, the endosperm is abundant and mealy, and the embryo is straight or curved.

KEY TO PRINCIPAL GENERA

Flowers subtended by involucres; ocreæ wanting, *Eriogonum*.
Flowers not subtended by involucres; ocreæ present.
  Calyx six-parted (rarely four).
    Stamens nine (very rarely six), *Rheum* (rhubarb).
    Stamens six, *Rumex* (dock).
  Calyx five-parted (rarely four).
    Achene much surpassing the calyx, *Fagopyrum* (buckwheat).
    Achene enclosed by the calyx, *Polygonum* (bistort, persicaria, knotweed, bindweed, etc.).

RHEUM RHAPONTICUM (**Rhubarb, Pie Plant**)

Roots, Stems, Leaves, Flowers.—This plant is a perennial from large, quite woody *rhizomes* which have a fibrous and

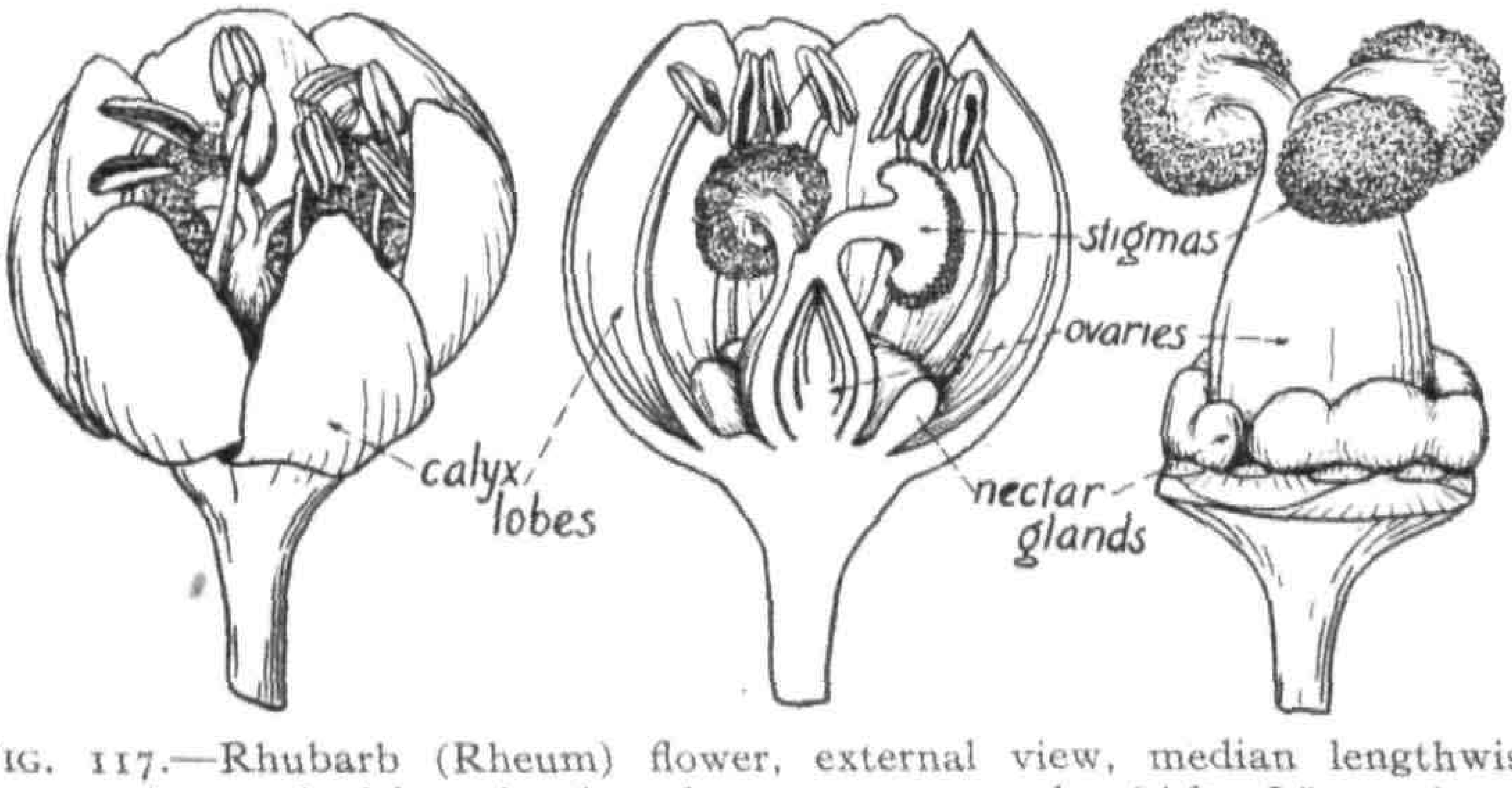


FIG. 117.—Rhubarb (Rheum) flower, external view, median lengthwise section, and with perianth and stamens removed. (*After Lürssen.*)

well-developed root system. The rhizome is used in the propagation of the plant. In the spring, a number of large leaves are sent up from the underground stem, and, sometime

during the season, there arise flower shoots, bearing elongated leafy *inflorescences*, crowded with small whitish flowers. Unless seed is desired, flower shoots should be promptly

FIG. 118.—Rhubarb (Rheum rhaponticum) plant in fruit.

removed, as they require considerable food supply which should go to the support of the roots. The *leaves* are large, circular in outline, cordate at the base, and with sinuate veins beneath; leaf petioles are semi-cylindrical and bear membranous ocreæ. The *flowers* are on short, jointed pedicels and

occur in fascicles, each of which is a raceme; the entire inflorescence is paniculate. The flowers (Fig. 117) are small, greenish white and perfect; the calyx is six-parted, persistent, and becomes enlarged somewhat in the fruit (Fig. 119); there are nine stamens; the ovary is three-angled and bears three short, recurved styles, with large stigmas.

Self-pollination is prevented to a large degree by the maturation of anthers before the stigmas. Stigmas of flowers below on the inflorescence receive pollen from the anthers of younger flowers borne above them. Pollen is disseminated by wind, insects, and gravity.

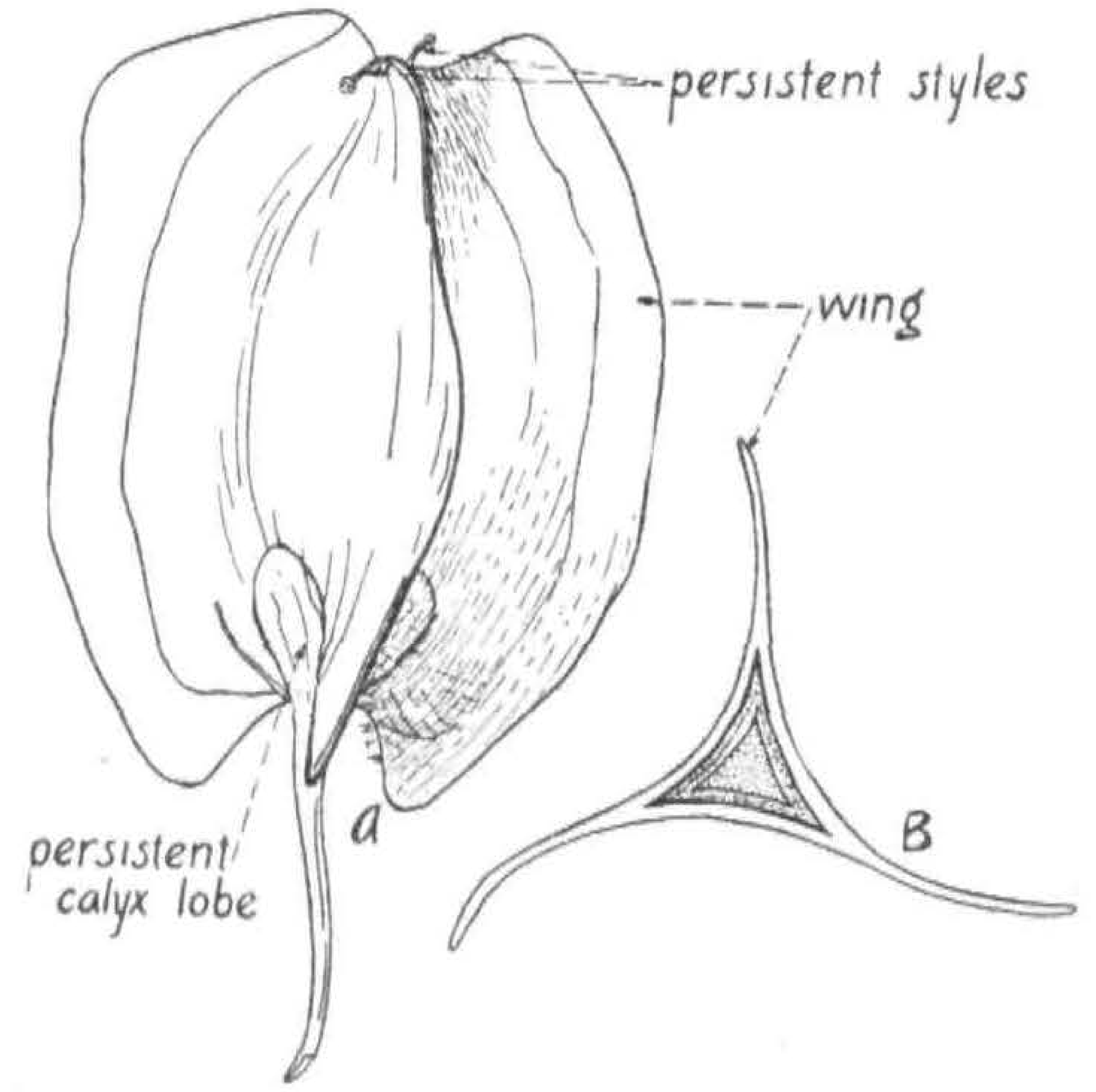


FIG. 119.—Fruit of rhubarb (Rheum rhaponticum). A, external view; B, cross-section. × 5.

Fruit.—Rhubarb fruit (Fig. 119) is an achene surrounded at the base with the persistent remains of the perianth; it has three broad, thin wings which are traversed by a longitudinal nerve running near the margin; it is tipped by a small persistent style. The seeds are three-angled, conforming in shape to the fruit; the testa is thin and red; the hilum and micropyle are basal; the endosperm is abundant and sur-

rounds the large straight embryo. Good-sized plants can be raised from seed in one season if it is planted early. The seedlings of rhubarb show interesting variation.

Geographical, and Varieties.—The common rhubarb is a native of Asia. It has become introduced into many countries of the temperate climates. It is a cool season crop that will withstand summer heat, and the roots winter freezing. It is claimed that a number of the varieties now grown are hybrids between *R. rhaponticum*, *R. undulatum* and *R. palmatum*. The principal varieties grown are Linnæus, Strawberry and Crimson Winter. There are a number or ornamental species of *Rheum*, most of which are distinguished from common rhubarb by their more or less lobed leaves, the margins of which may be coarsely or finely toothed.

Uses.—Rhubarb or pie plant is a vegetable used for its large, acid leaf stalks, which are of the best quality early in the season. The leaf stalks are usually made into pies or sauce, and occasionally wine is made from the juice.

FAGOPYRUM VULGARE (Common Buckwheat)

Roots.—Common buckwheat is an annual, from 2 to 4 feet tall. It has a small root system. There is a single primary root which may reach down to a distance of 3 or 4 feet; side roots are given off along the primary, but they do not extend far into the soil. Buckwheat differs from the true cereals, in the possession of a single primary root, and a much less extensive root system.

Stems.—The stems are quite succulent, smooth, except at the nodes, and strongly grooved. Each seed gives rise to but one stem which may branch freely, but, unlike grasses, no "suckers" or "tillers" are produced. The amount of branching depends upon the thickness of seeding; the plants branch freely when not crowded and feebly when crowded. The young stems vary from green to red, and turn brown with age.

Leaves.—The leaves are alternately arranged on the stem and characteristically hastate (halberd-shaped) (Fig. 116), or triangular heart-shaped; they may be sessile or short-petioled, and bear an ocrea (Fig. 116), which soon falls off.

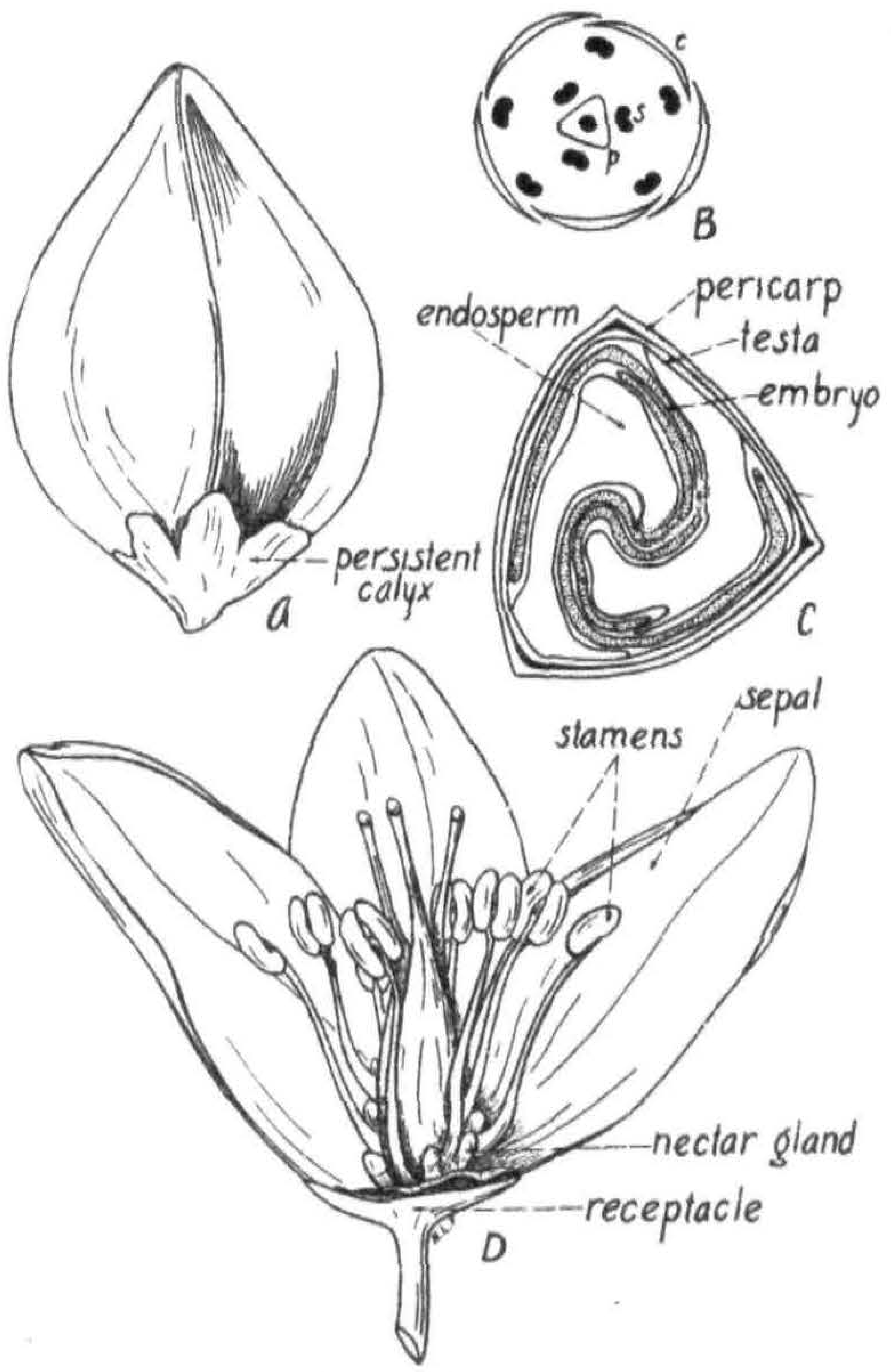


FIG. 129.—Common buckwheat (Fagopyrum vulgare). *A*, achene; *B*, floral diagram; *C*, cross-section of fruit; *D*, flower. (*B after Wossidlo; C after Stevens.*)

Inflorescence.—The inflorescence is a raceme which may be either paniculate or corymbose (a corymb is a flat-topped raceme type of inflorescence); it is terminal and axillary, many-flowered, and erect or slightly dropping.

needed. The notch-seeded buckwheat (*F. emarginatum*), a form cultivated in northeastern India and China, is distinguished from the preceding by having the angles of the smooth hull prolonged into wide, rounded wings.

Varieties.—Three varieties of common buckwheat are grown in the United States: Japanese, silver hull, and common gray. They may be distinguished by the following key:

KEY TO VARIETIES OF COMMON BUCKWHEAT

Faces of grain slightly concave; angles extended into very short wings, *Common gray*.
Faces of grain flat; angles not extended into wings.
  Grain small and plump, *Silver hull*.
  Grain large and not so plump, *Japanese*.

Environmental Relations.—Buckwheat is a temperate-climate plant, finding the best conditions for growth where the summers are cool and moderately moist. Dry, hot weather is inimical to the proper setting of the fruit. Buckwheat has a water requirement intermediate between that of barley and oats. Buckwheat is known to do well on poor soils, even those in which the drainage is such as to make it impossible to grow the small cereals profitably.

Uses.—The principal use of buckwheat is in the manufacture of pancake flour. As a food for stock, it is used in various forms. The whole grain is sometimes fed to poultry, hogs and cattle. Usually, however, the hulls are removed from the grain, and the seeds ground, before feeding to hogs. The middlings (hulls mixed with bran) are prized as a stock feed. Buckwheat straw is used both as a feed and a bedding for stock. Honey from buckwheat flowers has always possessed a high reputation for flavor. Buckwheat will grow well on poor soil—a soil that will not support true cereals. Therefore, it may be used as a green-manure crop.

References

MORSE, J. F.: The New Rhubarb Culture. Orange Judd Co., 1912.

STEVENS, N. E.: The Morphology of the Seed of Buckwheat. Bot. Gaz., 53: 59–66, 1912.

Observations on Heterostylous Plants. Bot. Gaz., 53: 277–308, 1912.

TSUTSUMI, OCHIMURA: Studies on the Buckwheat. Bot. Mag. (Tokyo), 8: 288–291; 417–421, 1894.

WILLIAMS, F. N.: Primary Characters in the Species of Rheum. 29: 292–295, 1891.

CHAPTER XXIII

CHENOPODIACEÆ (Goosefoot Family)

This family is widely distributed geographically. Its representatives are, for the most part, saline plants found near the ocean or in deserts and steppes. They are characteristic plants of the alkaline swamps and meadows of the western United States. Plants that are able to grow in soils very rich in salts are designated *halophytes*. Of course the salinity of the soil solution retards the rate of water intake by the roots, and, consequently, halophytic plants are found with structural adaptations which prevent a rapid loss of water from the leaves. Our most typical halophytic plants are found within the goosefoot family.

From an economic standpoint, the family is of considerable importance. The principal cultivated forms are the beet and spinach. A large number are weeds, chief of which are goosefoot, pigweed, lamb's quarters, strawberry blite, and Russian thistle.

Stems and Leaves.—Members of the family are annual or perennial herbs, or shrubs (*Atriplex*, saltbush). The *stems* are cylindrical or angled, erect or decumbent. The *leaves* are usually alternate, rarely opposite, without stipules, simple, and entire, toothed or lobed.

Inflorescence and Flowers.—The flowers may occur in panicled spikes (beet), or in globular, axillary, sessile heads (*Blitum capitatum*, strawberry blite) or sometimes they are solitary in the axils (*Salsola*, Russian thistle). The *flowers* are usually small, greenish, and bractless (*Sarcobatus*, greasewood), or bracteolate (*Beta*). They are perfect (*Beta*),

pistillate (*Kochia*), polygamous (*Kochia*), monœcious (*Sarcobatus*), or diœcious (*Atriplex* spp.) They are usually regular. There are no *petals*. The *calyx* is three- to five-lobed or parted, rarely of one sepal (*Monolepis*), or is entirely wanting in the pistillate flowers of some genera (*Atriplex*). The calyx is persistent in the fruit. There are usually as many *stamens* as lobes of the perianth, rarely fewer (*Chenopodium* spp.); the filaments are commonly slender and bear longitudinally dehiscent, two-celled anthers. The *ovary* is superior, free from the calyx and one-celled; the styles are terminal, short or elongated, one to three in number, and bear capitate stigmas. It has a single, erect *ovule*.

Fruit.—The mature *fruit* is a utricle (one-seeded fruit with a loose pericarp) with membranous, leathery, or thin pericarp. The *seeds* may possess an abundance of endosperm (*Beta*, *Eurotia*, etc.), or none (*Sarcobatus*, *Salsola*); the embryo is spirally coiled (Fig. 122) (*Salsola*), annular (*Beta*), or conduplicate (*Salicornia*).

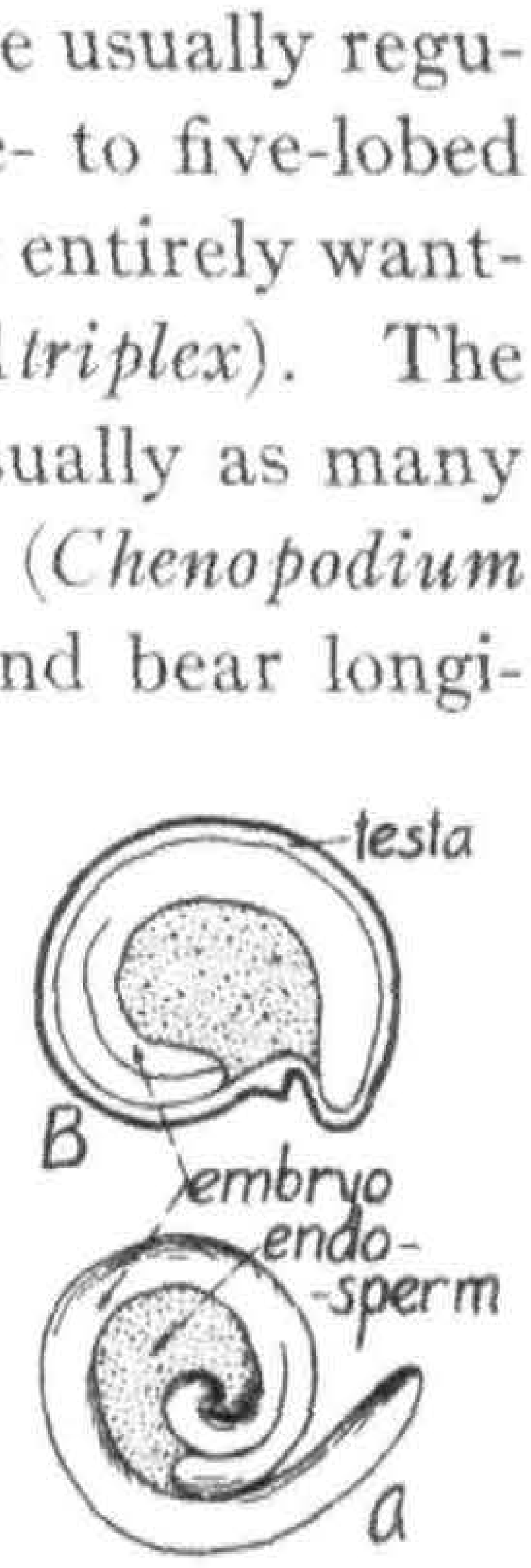


FIG. 122.—*A*, spiral embryo of Sarcobatus; *B*, annular embryo of Beta.

KEY TO PRINCIPAL GENERA

Embryo spirally coiled (Fig. 122); endosperm little or none.
  Shrubs, *Sarcobatus* (greasewood).
  Herbs, *Salsola* (Russian thistle).
Embryo not spirally coiled, partly or completely annular (Fig. 122); endosperm abundant.
  Flowers perfect (polygamous in *Kochia*).
    Calyx with five lobes, about the base of which is developed a wing, *Kochia*.
    Calyx wingless, persistent.
      Lobes of calyx becoming fleshy and bright red, *Blitum* (strawberry blite).
      Lobes of the calyx not becoming fleshy, and never red in color.
        Developing large fleshy tap roots, *Beta* (beet).
        Tap roots not fleshy, *Chenopodium* (goosefoot, lamb's quarters, pig weed).

Flowers monœcious or diœcious.
  Bractlets silky-hairy, *Eurotia* (winter sage).
  Bractlets not silky-hairy.
    Pistillate flowers without a calyx, *Atriplex* (orache).
    Pistillate flowers with a calyx, *Spinacia* (spinach).

SPINACIA OLERACEA (Spinach)

Description.—Spinach is an erect, smooth, annual *herb*. Early in the season, it throws out a number of large leaves, crowded near the ground surface. Somewhat later, a flower stalk is sent up to a distance of 2 or 3 feet. The *leaves* are

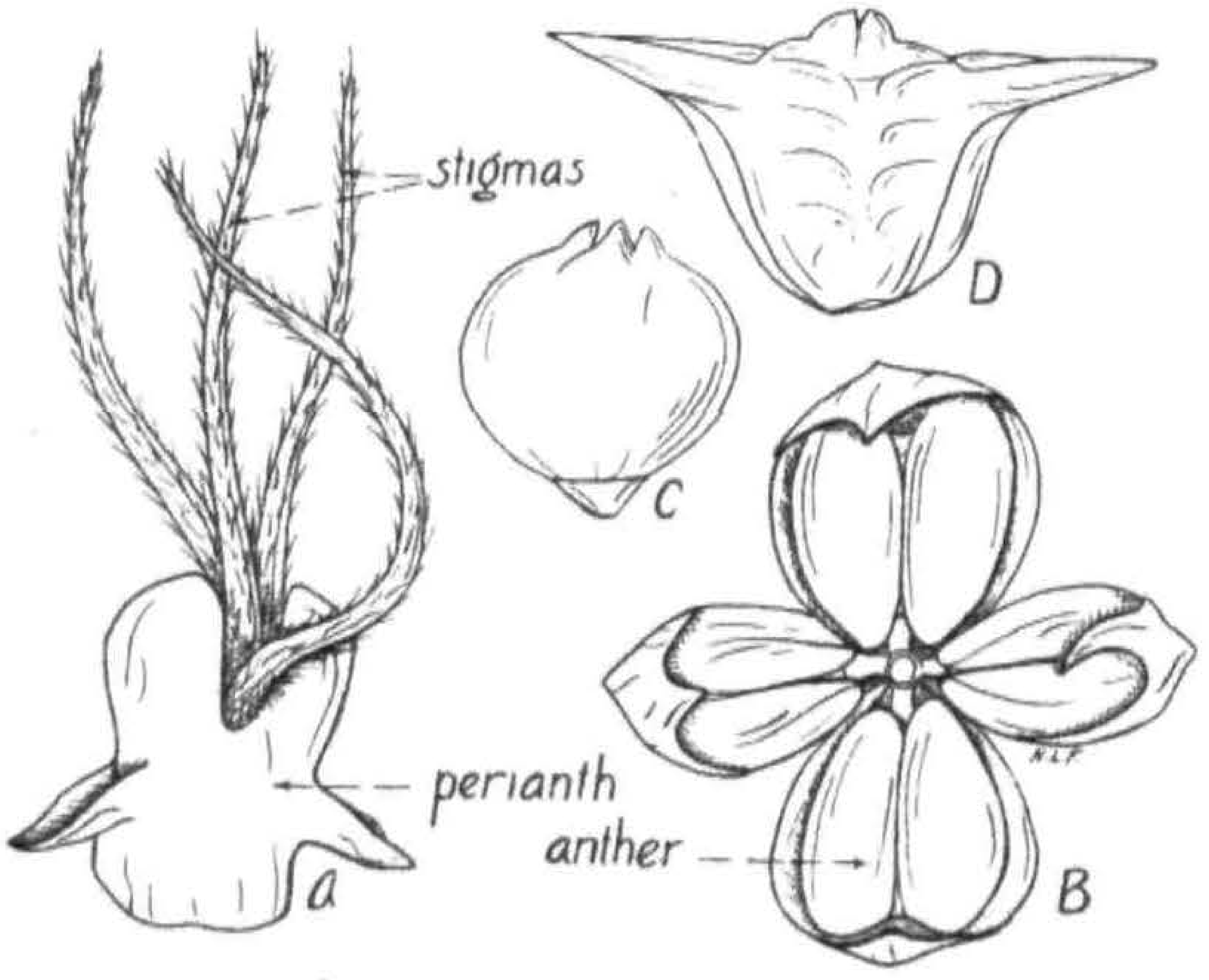


FIG. 123.—Spinach (Spinacea oleracea). *A*, pistillate flower of prickly-seeded spinach; *B*, staminate flower of same; *C*, fruit of smooth-seeded spinach; *D*, fruit of prickly-seeded spinach.

large, alternate, petioled, and triangular-ovate or arrow-shaped in outline. The *flowers* occur in axillary clusters. Staminate and pistillate flowers usually occur on different plants (diœcism), occasionally on separate inflorescences on the same plant (monœcism); and rarely flowers are perfect. The *staminate flowers* (Fig. 123, B) have a four- to five-parted calyx and four to five stamens inserted at the base of

the perianth. *Pistillate flowers* (Fig. 123, A) have a two- to four-divided perianth which encloses the fruit. The single *ovary* bears four to five stigmas, united at the base. The *mature fruit* (Fig. 123, C, D) is a utricle consisting of a compressed seed surrounded by the cartilaginous calyx lobes, which are either smooth or spiny, and by a membranous pericarp. The *seed* is compressed, about the size of beet seed, and has an annular embryo surrounding the floury endosperm.

Spinach is a native of southwestern Asia. It has become widely spread in cultivation. It is a cool-season crop requiring an abundance of water. It runs to seed in warm weather.

Other Plants Named "Spinach."—There are two types of "spinach" which do not belong to the genus *Spinacia:* New Zealand Spinach (*Tetragonia expansa*) and Mountain spinach, or orache (*Atriplex hortensis*). New Zealand spinach or New Zealand ice plant, is a member of the family Mesembryaceæ, and a native of New Zealand. It is grown as summer "greens." The plant is low, but profusely branching and spreading; the numerous, upright lateral branches are beset with tender leaves; the tips of these branches are the edible portion of the plant. The alternate triangular leaves are rather fleshy; the flowers are axillary, small, yellowish green, and without petals; the fruit is nut-like, and has one to nine locules, each of which is one-seeded. Mountain spinach or orache is more closely related to the common species, belonging in fact, to the same tribe. It is a plant 4 to 6 feet tall, branching, and bears an abundance of fruit. It not only differs from common spinach in its more erect habit but in its floral and fruit characters. The pistillate flowers do not have a perianth, but in fruit the seed is enclosed by a pair of compressed bracts which become enlarged and wing-like.

Flowers monœcious or diœcious.
  Bractlets silky-hairy, *Eurotia* (winter sage).
  Bractlets not silky-hairy.
    Pistillate flowers without a calyx, *Atriplex* (orache).
    Pistillate flowers with a calyx, *Spinacia* (spinach).

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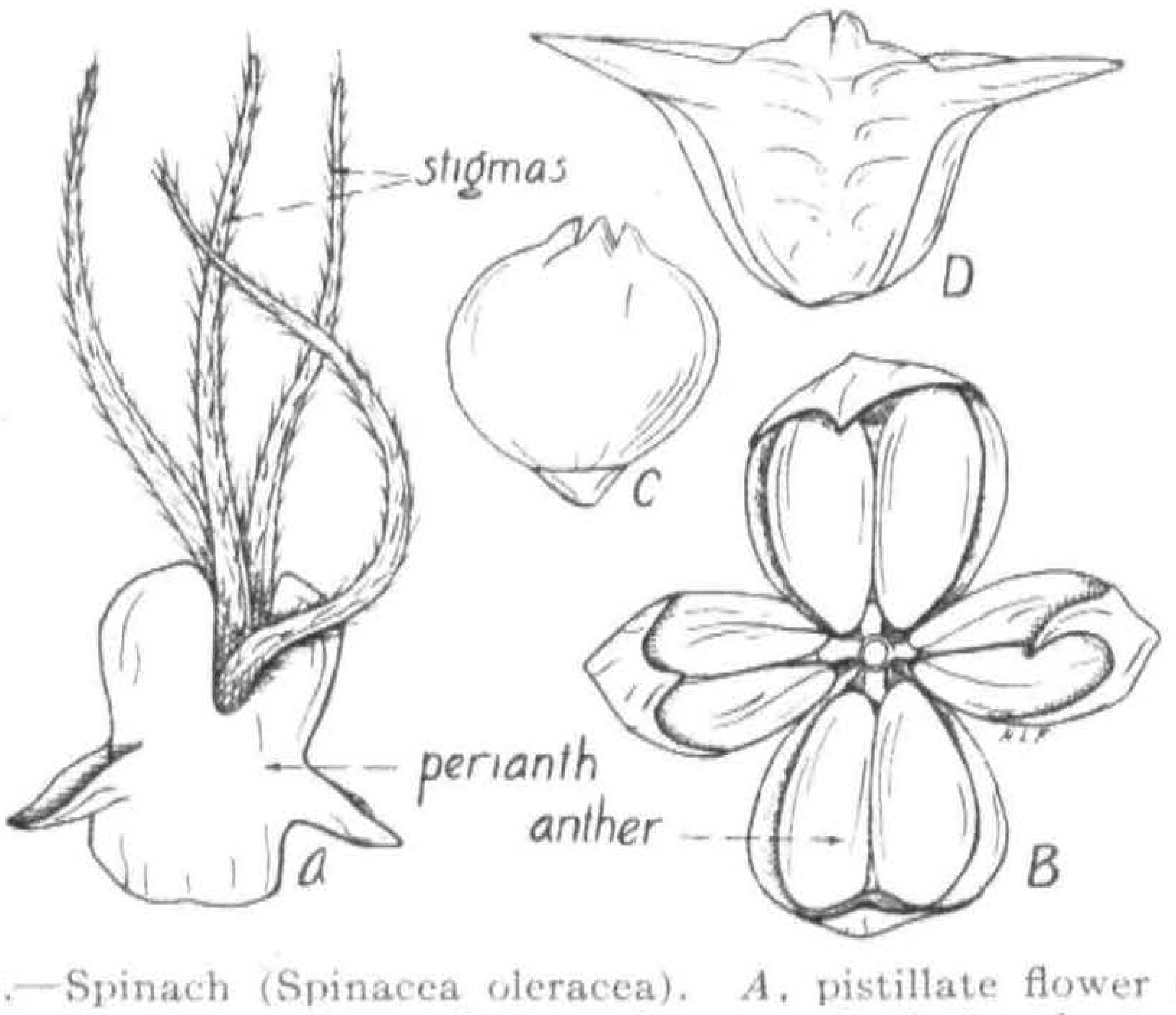

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Groups of True Spinach.—Kinney places the varieties of true spinach (*Spinacia*) into four types or groups, which may be distinguished by the following key:

KEY TO GROUPS OF SPINACH

"Seeds" prickly, *Prickly-seeded group.*
"Seeds" smooth.
  Ends and lobes of leaves rounded; plants compact in habit, *Round-leaved group.*
  Ends and lobes of leaves more or less pointed.
    Plants large, leaves long, and spreading on the ground, *Thick-leaved group.*
    Plants not so spreading, more vase-form and erect, on account of the stronger leaf stalks, *Norfolk or Bloomsdale group.*

It was formerly thought that prickly-seeded spinach was more hardy than the smooth-seeded varieties, but a number of the latter have proven quite as hardy as prickly-seeded ones. Long Season, King of Denmark and Triumph are important varieties in the round-leaved group; Viroflay, Broad-leaved Flanders and Long Standing in the thick-leaved group; Bloomsdale Savoy (Norfolk Savoy and Virginia Savoy in the Norfolk group.

Spinach is one of the foremost plants for "greens," or for use as a pot herb, and is now canned in large quantities.

BETA VULGARIS (Beet)

Botanical Groups.—The above is the only species of the genus *Beta* of any economic importance. It is a complex species, however, separated into a number of rather distinct groups as follows:

1. Sugar beet.
2. Mangel-wurzels or mangels.
3. Common garden beet.
4. Leaf beets.

(*a*) Chard or Swiss chard.

(*b*) Ornamental or foliage beets.

The Wild Beet.—Along the coast of southern Europe, there grows the so-called sea beet (*Beta maritima*) which has a tough, slender root. It is considered that the cultivated groups of beets have been derived from some form of this wild beet.

This plant shows remarkable variability; it behaves either as an annual, a biennial, or a perennial. Normally, the individual produces flowers and fruit the first growing season; occasionally, these appear for the first time the second year; and sometimes the plant survives six or seven years, and produces seed every year. The biennial character in some instances is fixed. For example, some two-year individuals will produce from seed all biennial plants, whereas other two-year individuals will give all annuals. Experiments with the wild beet demonstrate that even after two years of selection, marked increase in the weight of the root, in sugar per cent. and decrease in woodiness results. In the fifth year of culture, the wild beet has been brought more or less to the type of the cultivated sugar beet, and individuals weighing as much as six pounds and with 15 per cent. sugar have been secured.

SUGAR BEET

The sugar beet is a biennial, storing up food the first year in the crown (fleshy stem) and tap root from which aerial shoots are produced the second year.

Root.—The "beet" itself is, for the most part, an enlarged tap root. The "crown" of the beet is developed from hypocotyl. The root part of the beet may be distinguished from the hypocotyl portion (stem) by the two opposite, longitudinal rows of secondary roots (Fig. 5). The tap root extends almost straight downward, and the lower portion be-

comes small and thread-like and commonly reaches a depth of 4 feet and often 6 or 7 feet. The lateral roots and rootlets are very abundant. The first 6 to 8 inches of the root, however, are almost free of side roots. The upper laterals are the largest of the branch roots and extend farthest

FIG. 124.—Sugar beet plant in full fruit.

in the soil, spreading almost horizontally 2 to 3 feet. The lower laterals are more vertical, and those near the very tip almost parallel with the tap root.

Stems.—The upper part (crown) of the sugar beet is hypocotyl, *i.e.*, stem. This is a very much shortened fleshy stem with the leaves crowded at the apex. The second year, it sends up, from terminal and axillary buds, stout, angular,

branching stems to a height of 3 or 4 feet; these stems give rise to flowering branches (Fig. 124).

Shape and Structure of Beet (Tap Root and Hypocotyl). *Beet Shape and Size, and Sugar Content.*—There is great variation in the shape and size of sugar beets. Some importance has been attached to the correlation between sugar content and beet shape and size. This relation, however, is of little significance. It has recently been shown that differences in the size and sugar content of individual beet roots are fluctuations, and show no evidence of inheritance. It is true that uniformity of type is desirable, but any attempt to judge of the sugar content of an individual beet by the shape and size is useless. Beets with a large crown are undesirable, because of the low sugar per cent. of the crown tissue and the high percentage of inorganic salts and other "impurities" which it contains. It has been pointed out that sugar beet improvement depends upon the occurrence and selection of mutations.

Anatomical Structure and Sugar Content.—The researches of a number of European investigators have shown that the anatomical structure of the sugar beet is correlated with sugar content. In general, beets with a high percentage of sugar have a finer structure than those with a low percentage. A cross or lengthwise section of a beet shows it to be made up, for the most part, of a ground tissue penetrated by groups of vessels. In cross-section (Fig. 125), these groups of vessels take a circular form, being separated from each other by parenchyma tissue. At the center of the beet, the bundles are close together, forming the so-called "star." The tissue that separates vessels is composed of two kinds of parenchyma cells: small cells surrounding the vessels, and large ones farther removed. The smaller parenchyma cells are rich in sugar, while the larger ones are principally water storage cells, poor in sugar. Hence, beets with a predominance of small-

celled parenchyma are richer in sugar than those in which large water storage cells predominate. It must not be assumed from this that it would be possible to find conspicuous differences in the anatomical structure of beets varying 1 or 2 per cent. in sugar. Furthermore, a certain microscopical appearance is not to be associated with a given sugar content.

Distribution of Sugar in the Beet.—Fig. 126 shows that the beet root is divided into various zones differing as to their sugar content. The sugar content decreases from a point below the broadest portion of the root to the crown and tip.

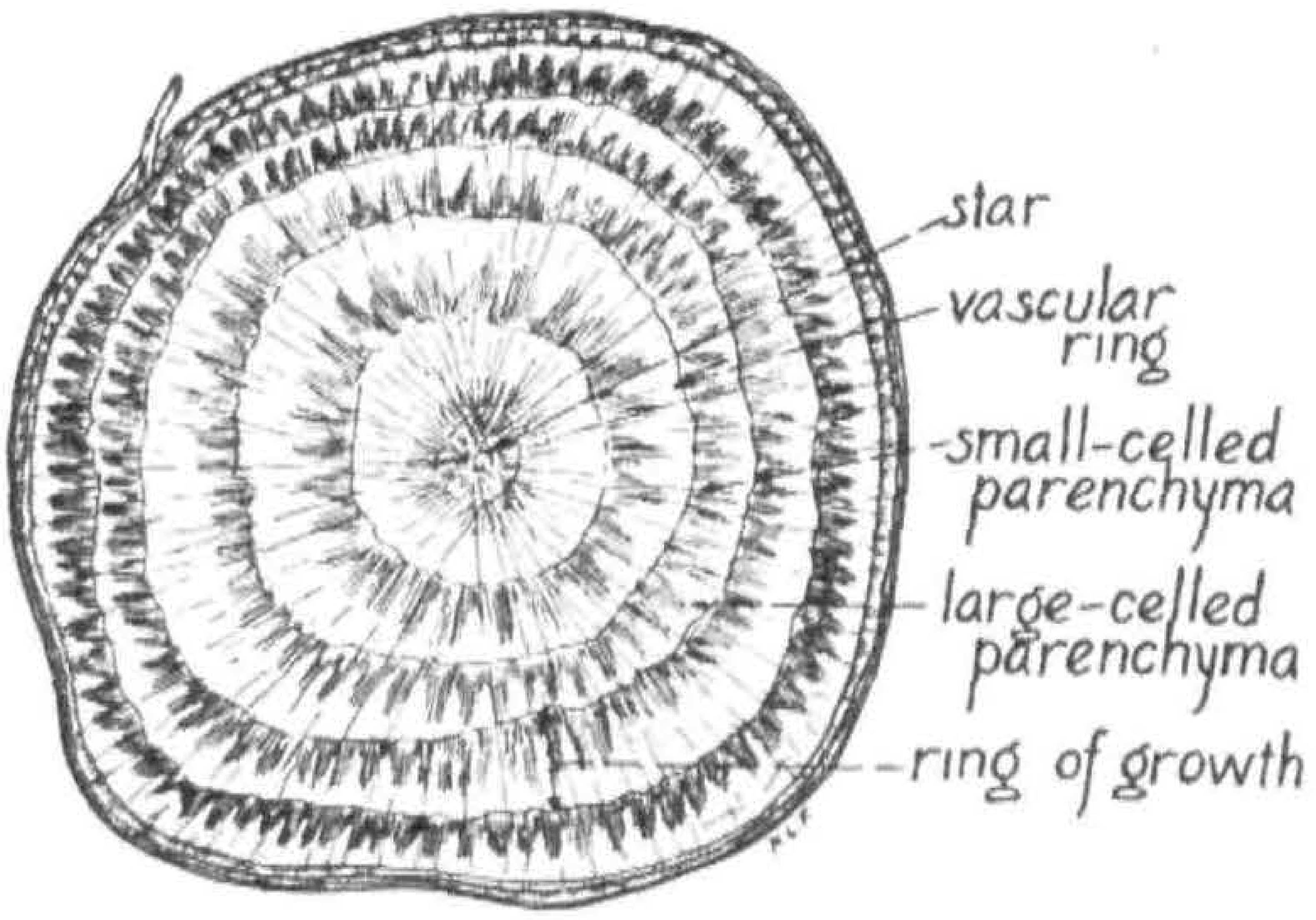


FIG. 125.—Diagrammatic cross-section of sugar beet root.

Factors Influencing the Sugar Per Cent. in the Sugar Beet.—There are recognized "yield strains" and "sugar strains" of sugar beets. But in any strain of beets, there are quite marked variations in the sugar per cent. of representative samples grown under different climatic conditions and, of samples from fields differing in their cultural treatment, crop history and soil type. In regions where high temperatures extend over a long period, beets are produced which are low in sugar per cent. The temperature requirements of the sugar beet have limited its growth from the sugar per cent. standpoint to the more northern belt of the United States.

Shading or weak lighting decreases the sugar per cent. Late rains and late irrigations have as a rule a depressing effect on the sugar per cent. Heavy applications of manure or a cropping system which favors the accumulation of ni-

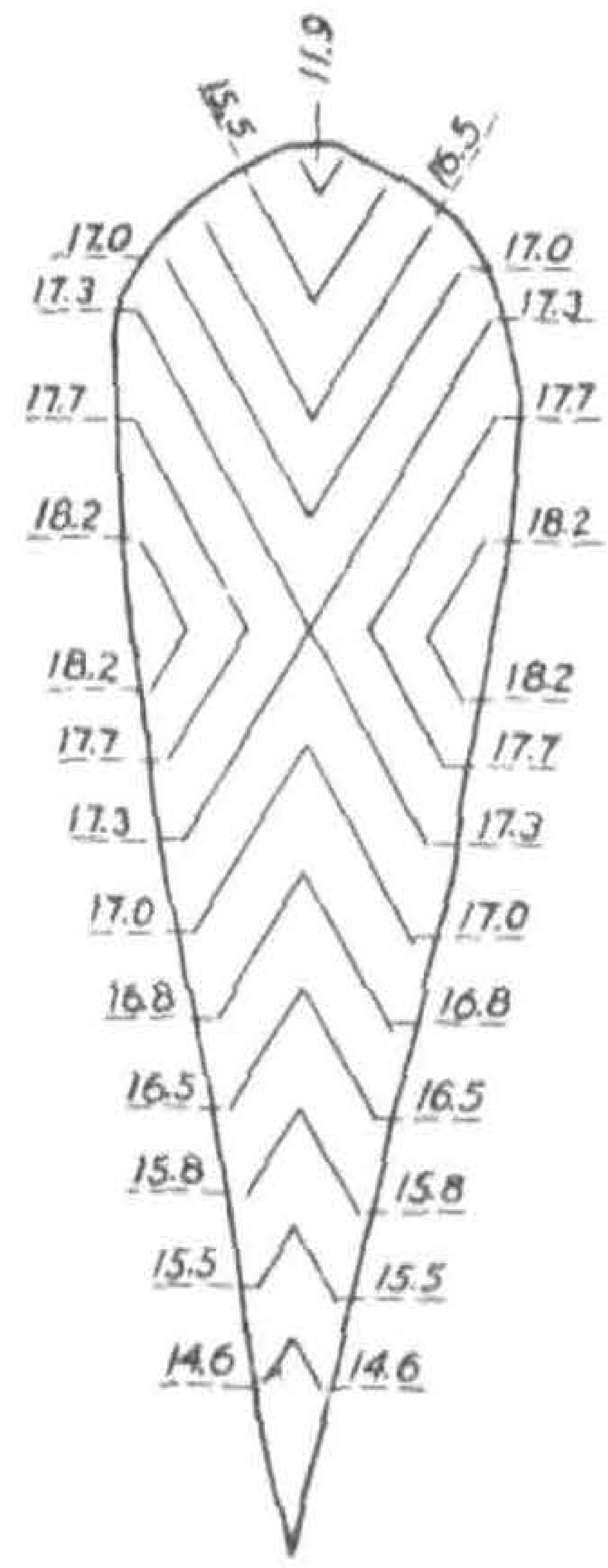


FIG. 126.—Diagram showing distribution of sugar in an average sugar beet. (*After Molinari.*)

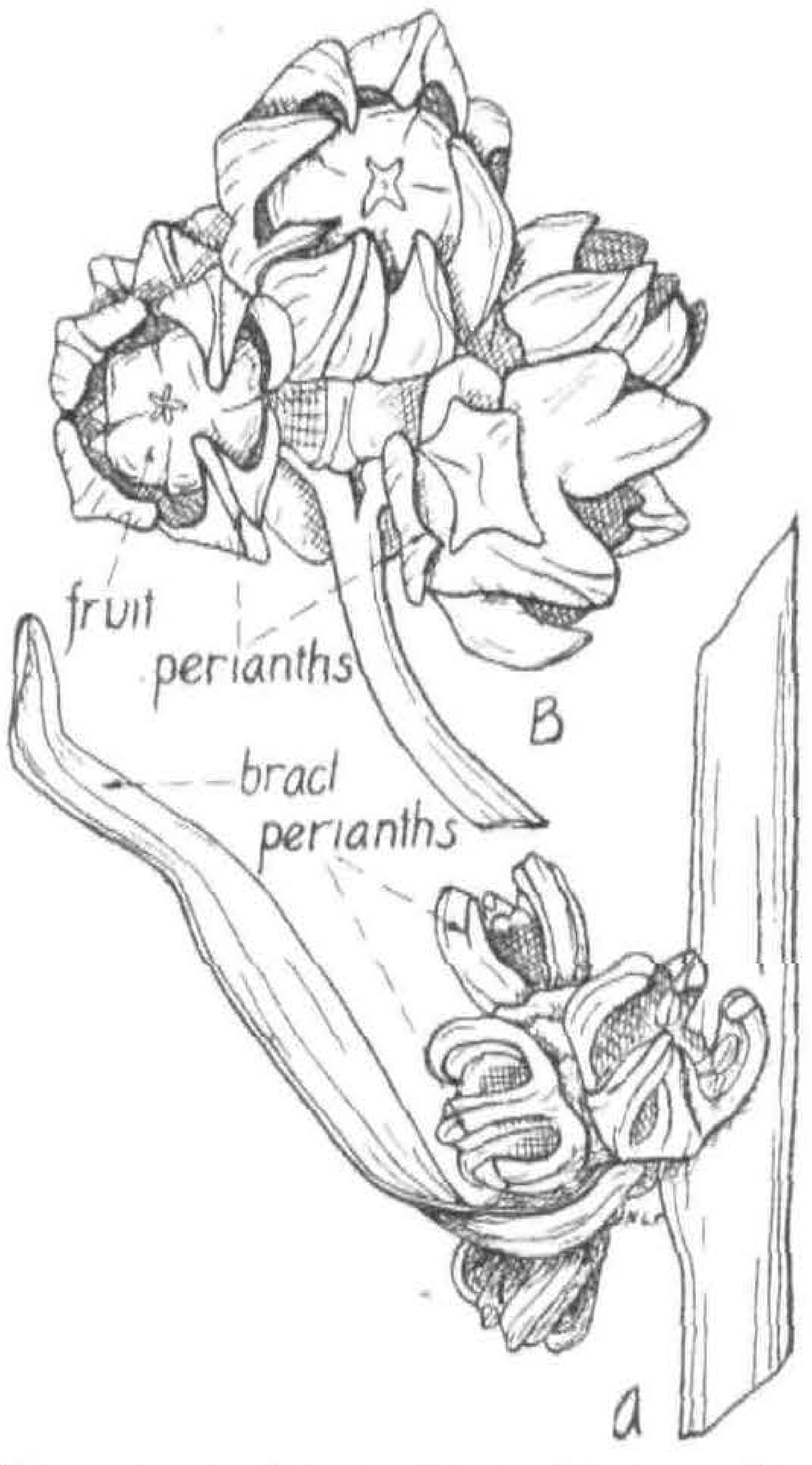


FIG. 127.—Sugar beet (Beta vulgaris). *A*, flowers grouped in the axil of a bract; *B*, cluster of flowers which fuse to form a multiple germ beet "seed."

trates in the soil, tend to lower the sugar per cent. Moreover, increasing the soil area per beet tends to decrease the percentage of sugar.

Crossing of Vascular Bundles in Crown.—In longitudinal section of a beet, it will be seen that there is a crossing of the vascular bundles in the stem (crown). The oldest part of the beet is the center; new rings of growth are placed upon these, while the new leaves come from the center of the crown.

Hence, there is a crossing of the older and younger bundles that lead into the leaves.

Rings of Growth.—The rings of growth vary in number, depending upon the length of the growing season. Ordinarily, six to ten rings complete their growth.

At about the time when the first pair of true foliage leaves begins to appear, the pericycle of the young root becomes active, its cells divide and become transformed into secondary cortex. As a result of the growth of the secondary cortex, the primary cortex together with the endodermis is broken and finally sloughed off. The process of

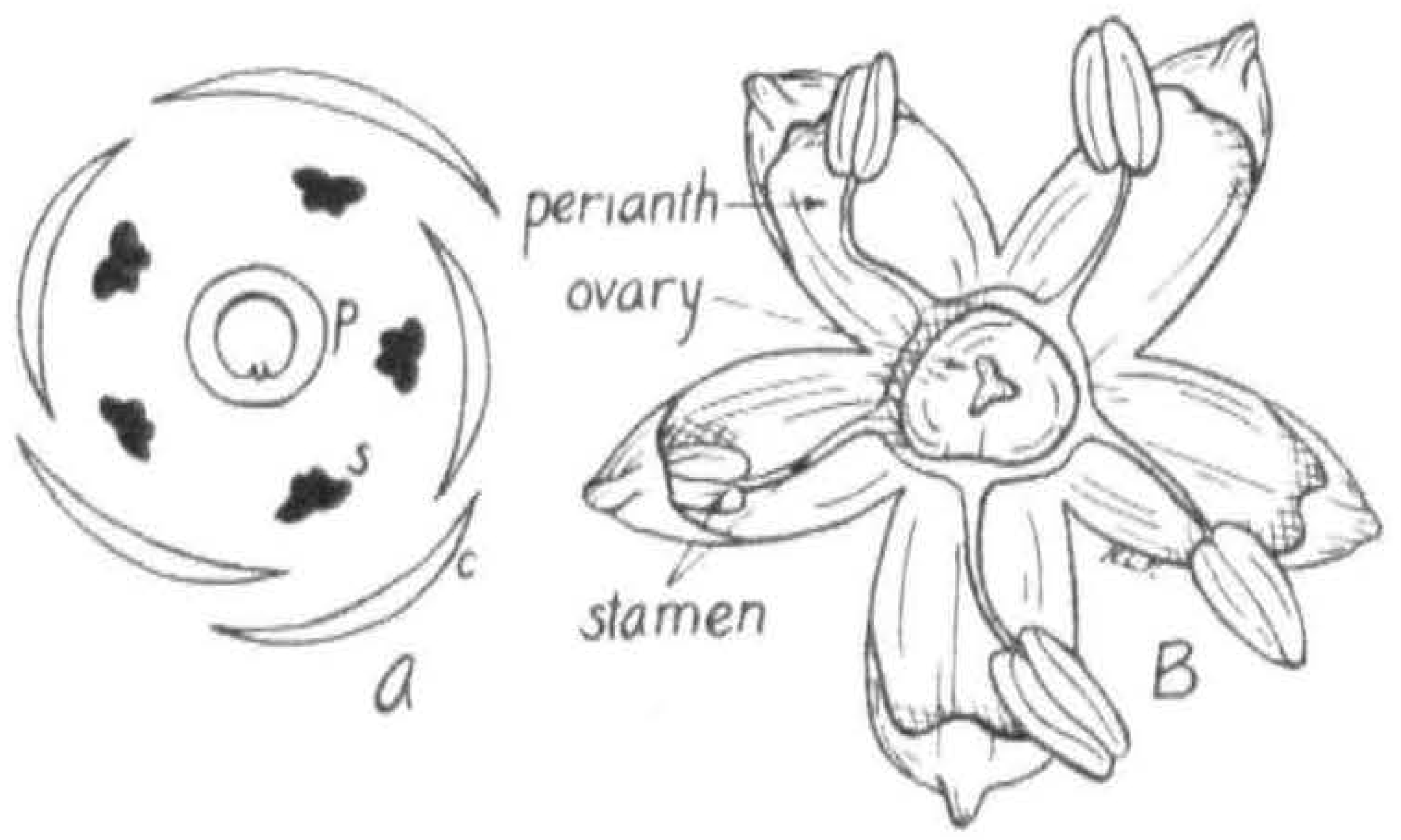


FIG. 128.—Beet (Beta vulgaris). *A*, floral diagram; *B*, flower, face view. (*A after Bessey.*)

discarding the primary cortex of the root is ended by the time the plant has three pairs of true leaves. In this secondary cortex parenchyma, formed by the division of pericycle cells, a new meristematic layer (cambium) is formed, which lays down xylem or wood tissue on its inside, and a relatively larger amount of parenchyma tissue (phloem) on its outer side. Soon, this cambium ceases its activity, and a new cambium originates at the outer limit of the parenchyma tissue. This process is repeated, each cambium ring remaining active but for a short period of several weeks.

Leaves.—A cluster of large leaves is developed from the crown of the beet during the first season. The oldest leaves are on the outside, the youngest toward the center. Each leaf has a long petiole which broadens out at the base; the blade is large and roughly triangular in shape at the base, and longer than broad; the veins are prominent.

Inflorescence.—The inflorescences are loosely spicate and terminal. The flowers are arranged along an axis, singly or in dense, sessile clusters, each of which is subtended by a small bract. Fig. 127, A shows a characteristic cluster of beet flowers in the axis of a bract.

Flowers.—Beet flowers are perfect. The perianth consists of five parts united below to the base of the ovary (Fig. 128). There are five stamens opposite to and partially attached to the perianth ring. The ovary is half-inferior, that is, partially imbedded in the flesh of the receptacle, one-celled and one- to three-seeded. There are two to three short, awl-shaped stigmas, united at the base.

Pollination and Fertilization.—The beet flower is protandrous. It has been shown that "self-fertilization" (autogamy) does not take place, and that "close fertilization" (geitonogamy) is usually ineffective. It has also been demonstrated that thrips voluntarily travel from plant to plant, and positively assist in pollination of beet flowers. Bees are of little consequence in this process. Wind is the chief factor in beet pollen dissemination.

Fruit and Seed.—The ripened ovary of each flower is imbedded in the receptacle and the base of the perianth. The fruit is hard and nut-like, and contains a single, dark, smooth seed. The beet seed of the market is frequently called the "*seed ball.*" The "seed ball" usually contains a number of germs; however, in some cases a single germ is produced. The multiple-germ beet seed arises when the flowers are in clusters; in this case, the parts of the several

flowers stick together forming a several-seeded mass, the "seed ball." If the flower stands by itself on the stem, a *single-germ beet seed* is produced. The single flowers are usually located at points on the stem where a branch arises. According to this, a highly branched inflorescence will produce a greater proportion of single flowers.

It must be borne in mind that the so-called "beet seed" is in reality a fruit, that a multiple-germ seed consists of several one-seeded fruits, and a single-germ seed of one one-seeded fruit.

There have been a number of investigations having to do with the relative value of large and small "seed balls." These show that medium sized seed balls are the best, in that they combine a high seed number with good weight and vigor of seedlings. A large seed ball may owe its size not to seeds with a greater amount of reserve material in them, but a large number of weak seeds or an exceptionally large percentage of seed ball parts which are not seeds.

The true seed is kidney-shaped and about the size of a turnip seed. The testa is thin, dark and smooth. The hilum and micropyle are basal. The white and floury endosperm lies in the middle of the seed, surrounded peripherally by the annular embryo (Fig. 122).

Seed Production.—For many years the beet industry in the United States was dependent almost wholly upon Europe for its supply of beet seed. However, at the beginning of the great war, considerable activity was manifested in the growing of beet seed at home, and as a result, we are now growing successfully large quantities of seed. Since the beet is a biennial, it is necessary to store the roots of the first year, and set them out the following season, in order to obtain seed. The "mother beets" may be tested for their sugar content before planting, and only those which show the desired percentage of sugar set out for seed production.

The testing and selection of mother plants for seed has resulted in a striking improvement in the quality of beets.

Germination, and the Seedling.—Under proper storage conditions sugar beet seed will germinate practically as well at the end of six or seven years after harvesting as it does the first year. There is a gradual decrease in viability after that period. The primary root is the first to appear. Soon, the cotyledons follow, pushing their way above ground. The seedling consists of a very short hypocotyl which scarcely appears above ground, two rather fleshy, glabrous, short-petioled, one-nerved cotyledons, and a tapering primary root which gives off a few red, fibrous laterals.

As was mentioned in a preceding paragraph, when the first pair of foliage leaves begins to appear, the root begins to push off the primary cortex. The sloughing off of this layer may give a dark, shredded appearance to the young root, which condition is often confused with a fungous disease "black root." In the interval between the appearance of the first pair and the fourth pair of foliage leaves, the root increases in thickness and length at a considerable rate, and by the time the young beet has eight foliage leaves, the length of the root which will be dug at harvest is determined. Of course, the fine roots will continue to penetrate deeper in the ground, and extend farther laterally in the soil as the season advances.

Types of Sugar Beets.—There are two well-known and common types of sugar beets: Kleinwanzlebener and Vilmorin. The Vilmorin beet is of French origin, and as compared with the Kleinwanzlebener, a German beet, is more circular in cross-section, smaller, has a lighter skin, and a much smaller top of leaves. The secondary root lines are straight in Vilmorin beets, and spiral in Kleinwanzlebener beets. The percentages of sugar in the two types are about the same. The tonnage of the Vilmorin is smaller.

Composition of Sugar Beets.—The following analyses of sugar beets were made by Headden.[1]

	German beet, grams	Michigan beet, grams	Colorado beet, grams	Montana beet, grams
Average weight trimmed	......	813.000	673.000	479.300
Water	74.550	78.000	75.800	74.603
Dry substance	25.450	22.000	24.200	25.370
Sugar	16.600	15.300	18.300	18.240
Total ash	0.800	0.701	0.820	2.680
Protein	0.706	0.769	0.543	0.436

Except in extreme cases, there seems to be little support for the statement that the greater the weight the less the sugar content of the beet. The composition of the beet is affected by age, disease, fertilizers, insufficient food supply, light, time of topping, rainfall, etc. The average sugar content of American grown beets is about 15 per cent. and the average yield per acre in approximately 10 tons. Frequently, the yields are more than 20 tons, and the sugar content 17 to 20 per cent.

Manufacture of Sugar.—The chief use of sugar beets is in the manufacture of sugar. The beet sugar industry has made very rapid development in this country. In the making of beet sugar, the topped beets are first washed, and then cut by machinery into narrow strips ("cossettes"). These strips are placed in diffusion vessels, treated with water at a temperature of about 80 to 84°C., and the sugar extracted by diffusion. The next process has to do with purifying the extracted juice. The juice is run into large tanks, where milk of lime is added to it. The liming is followed by the introduction of carbonic acid, which precipitates the lime as a carbonate and salts of the acids of the juice. The precipitate carries down most of the impurities in the juice. When the first "carbonation" process is about completed, the juice is heated nearly to the boiling point, filter-pressed, and the

[1] Colorado Agri. Exp. Sta. Bull. 183.

filtrate lead into a second carbonation tank. This is followed by treatment with sulphur dioxide, which removes or breaks down some of the coloring matter in the juice and thus improves the color of the sugar. The purified juice is concentrated by boiling, and crystallization brought about in vacuum evaporators. The material that comes from the vacuum evaporators is a mixture of crystals and molasses. This mixture ("masscuite") is placed in centrifugal machines lined with fine sieves; here the molasses is driven out and the sugar retained. The sugar is next fed into the granulator, where the crystals are separated from each other during the drying process. The molasses from the first boiling is again boiled, and further crystallization brought about.

By-products of Manufacture.—After the sugar has been removed from the sliced beets, there is left a substance known as "beet pulp." This is a valued stock food. However, it cannot be made the sole ration of an animal, as it is deficient in nitrogenous food materials. Beet pulp is sometimes dried, mixed with molasses, and fed to dairy cows. Molasses from the second boiling is also valued as a stock food. The refuse that accumulates in the purification process is sometimes employed as a fertilizer. It has been demonstrated that it is possible to manufacture fusel oil, alcohol, rum, and vinegar from the refuse molasses. There are many other ways of utilizing sugar-beet molasses.

COMMON GARDEN BEET

The botanical characters of the garden beet are very similar to those of sugar beet. As is well known, however, they are not so rich in sugar and differ from them in color, shape, and edible qualities.

Types.—As to color, there are two main groups of garden beets: (1) *Flesh red* (Early Blood Turnip, Eclipse, Egyptian, Detroit, Dark Red); and, (2) *Flesh yellow* (Early Yellow

Turnip, Golden Globe). Goff divides garden beets into four types as to shape:

1. Root oblate or top-shaped (Early Blood Turnip, Eclipse, Egyptian, etc.).

2. Root half long (Victoria).

3. Root oval (Strasbourg Pear-shaped, Dell's Black-leafed).

4. Root long-conical (Long Blood, Long Yellow).

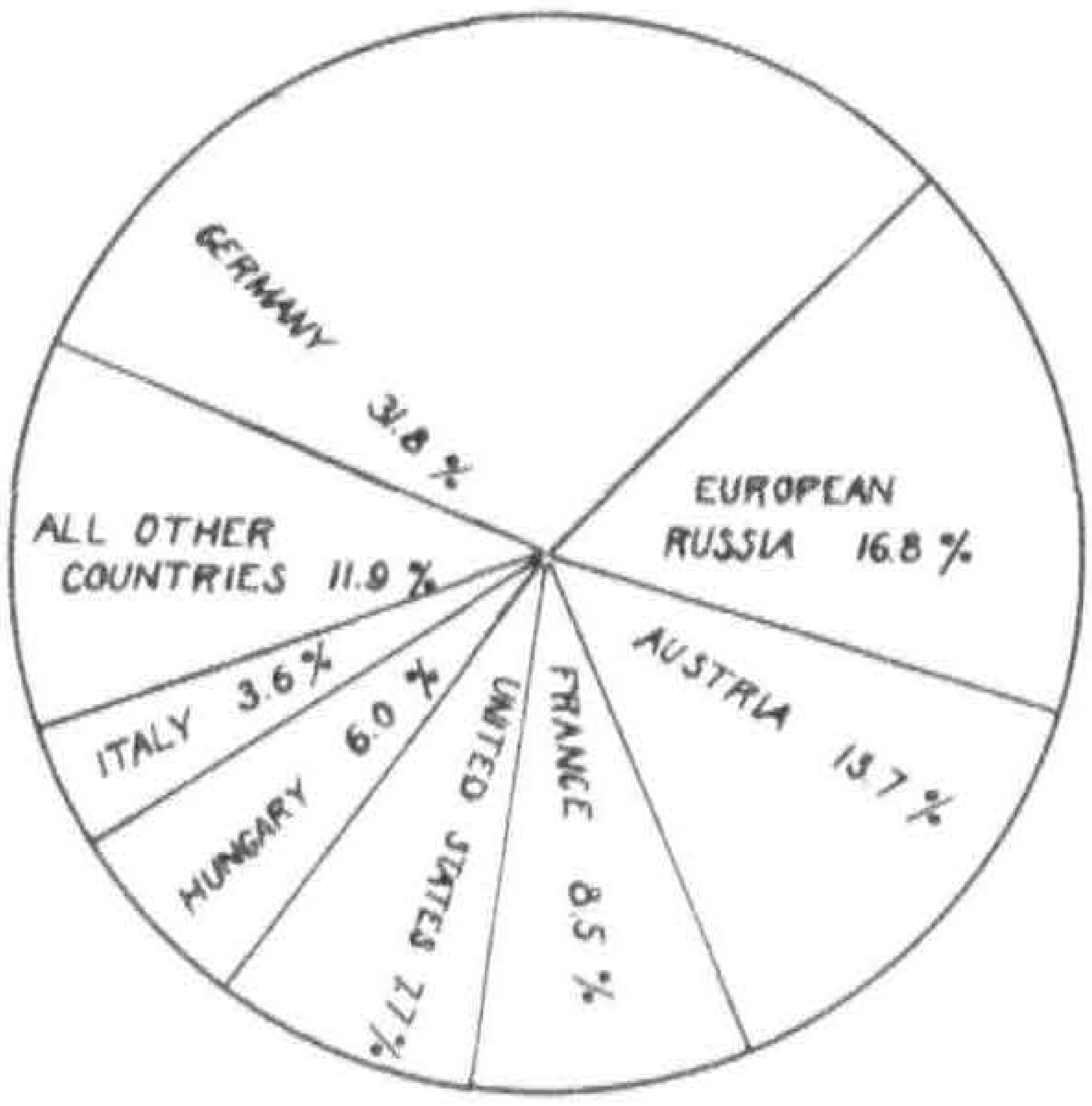


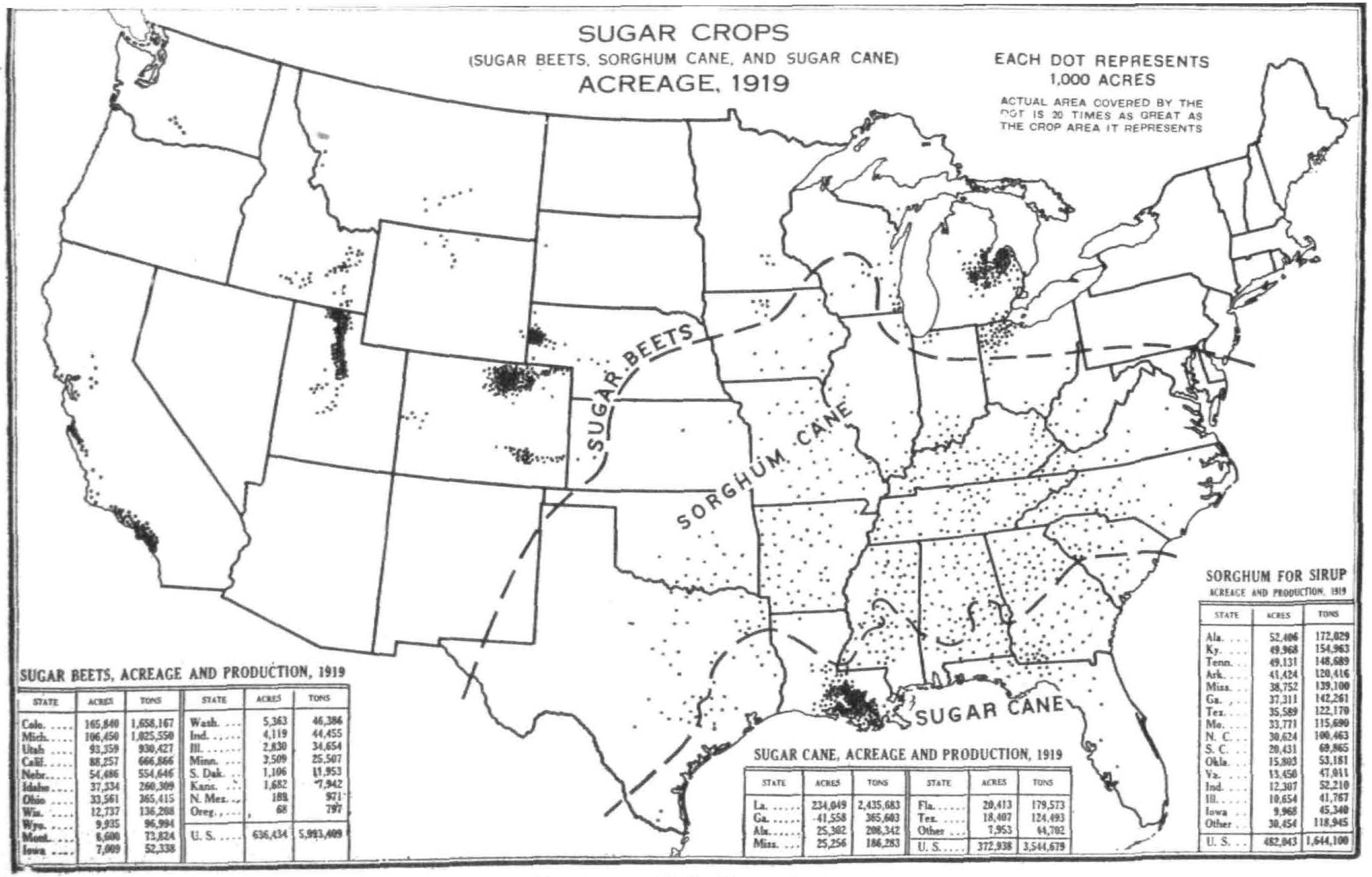
FIG. 129.—Percentage of the world's supply of beet sugar (raw) produced in the different countries, campaign of 1913–14.

Probably the most important early variety is Crosby's Egyptian, and the most important late variety Detroit Dark Red.

Uses.—Garden beets are mostly for table use. The flavor of early varieties is more delicate than that in later maturing ones. The roots are boiled, pickled, or mixed in salads. Considerable quantities are canned, and in some cases the common garden sorts are used for stock food.

CHARD

The edible "leaf beets" go under various names: Spinach beet, sea-kale beet, Swiss chard, silver beet, chard, and *Beta cycla*. The flowers and fruit are like those of the



SUGAR BEETS, ACREAGE AND PRODUCTION, 1919

STATE	ACRES	TONS	STATE	ACRES	TONS
Colo.	165,840	1,658,167	Wash. ...	5,363	46,386
Mich.	106,450	1,025,550	Ind.	4,119	44,455
Utah	93,359	930,427	Ill.	2,830	34,654
Calif.	88,257	666,866	Minn. ...	3,509	25,507
Nebr.	54,486	554,646	S. Dak. ..	1,106	11,953
Idaho	37,334	260,309	Kans. ...	1,682	7,942
Ohio	33,561	365,415	N. Mex. ..	188	971
Wis.	12,737	136,288	Oreg.	68	797
Wyo.	9,935	96,994			
Mont.	8,600	73,824	U. S.	636,434	5,993,409
Iowa	7,009	52,338			

SUGAR CANE, ACREAGE AND PRODUCTION, 1919

STATE	ACRES	TONS	STATE	ACRES	TONS
La.	234,049	2,435,683	Fla.	20,413	179,573
Ga.	41,558	365,603	Tex.	18,407	124,493
Ala.	25,302	208,342	Other ...	7,953	44,702
Miss. ...	25,256	186,283	U. S.	372,938	3,544,679

SORGHUM FOR SIRUP
ACREAGE AND PRODUCTION, 1919

STATE	ACRES	TONS
Ala. ...	52,406	172,029
Ky. ...	49,968	154,963
Tenn. ..	49,131	148,689
Ark. ...	41,424	120,416
Miss. ..	38,752	139,100
Ga. ...	37,311	142,261
Tex. ...	35,589	122,170
Mo. ...	33,771	115,690
N. C. ..	30,624	100,463
S. C. ..	20,431	69,865
Okla. ..	15,803	53,181
Va. ...	13,450	47,011
Ind. ...	12,307	52,210
Ill.	10,654	41,767
Iowa ..	9,968	45,340
Other ..	30,454	118,945
U. S. ..	482,043	1,644,100

common beet. Cultivation has changed its habit of growth, however, such that leaves, instead of roots have become developed.

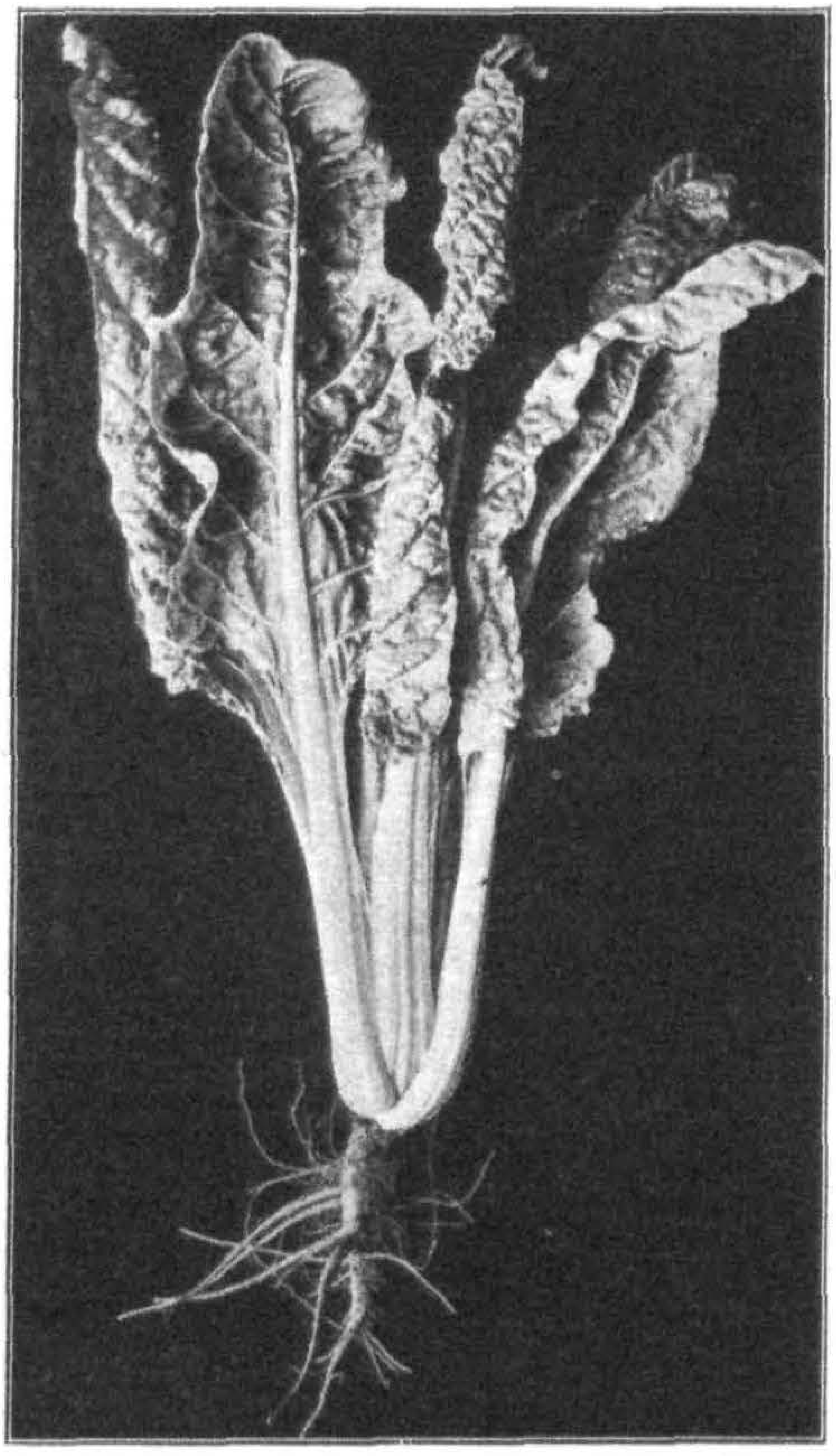


FIG. 131.—Chard or leaf beet (Beta vulgaris).

The plant is a biennial with a somewhat branched and thickened, but not fleshy, root system. The leaves are clustered at the surface of the ground (Fig. 131); they bear large, thick stalks and large blades. The leaf stalks are often as much as 2 feet long and 1 to 3 inches thick.

The chief variety grown in this country is Lucullus, one in which the leaves are heavily crumpled or "savoyed." Swiss chard is a variety with dark, green leaves. There are forms of chard with white, red or pink leaf stalks.

Chard is grown for its tender leaves and petioles. The leaves are boiled like spinach, and the petioles are served like asparagus.

MANGEL-WURZELS OR MANGELS

To this group belong the stock-feeding varieties of *Beta vulgaris*. The botanical characters are very similar to those given for the sugar beet.

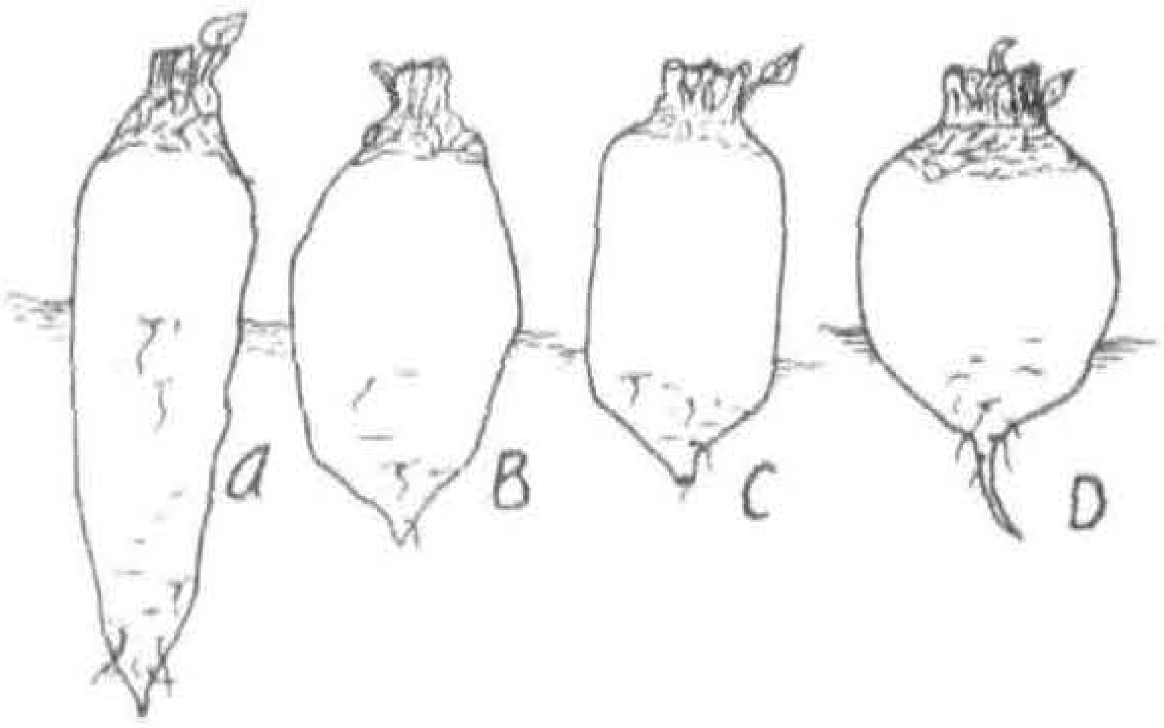


FIG. 132.—Types of mangels. *A*, long; *B*, intermediate; *C*, tankard; *D*, globe. (*After Percival.*)

Types.—As to shape, there are four well-recognized types of mangels (Fig. 132):

1. *Globe.*—In these varieties, the roots are globular, and project above ground for more than half their length (Yellow Globe, Orange Globe).

2. *Tankard.*—Varieties of this type have roots which are almost cylindrical, and narrow abruptly at both ends. The roots are comparatively small (Golden Tankard).

3. *Oval or "Intermediate."*—The roots in these are oval, and intermediate in shape between globe and long varieties. They vary in color (Giant Intermediate).

4. *Long.*—Roots of this type are several times longer than broad and project above the soil for a considerable propor-

tion of their length. They are heavy yielders. Both red and yellow-skinned varieties (Long Red, Long Yellow) occur. The ox-horn varieties have long twisted and horn-like roots.

Composition and Uses.—The mangels vary in sugar content from 3 to 8 per cent., the Golden Tankard and Globes having the highest percentage. Long varieties are relatively low in sugar content but produce a greater tonnage per acre. The water content varies from 85 to 92 per cent. Mangels are being extensively grown for stock food. They are one of the most important root crops. The *root crops* include all plants whose underground vegetative parts, such as rootstocks or roots, are utilized. Bulbs and tubers, however, are usually excluded. Examples of root crops are beets, mangels, turnips, carrots, rutabagas, sweet potatoes, and artichokes. Root crops are used for human food and also for forage. It must be kept in mind that all "root crops" are not wholly roots, morphologically, but that in some, such as the carrot, turnip, rutabaga, mangel and beet, the lower two-thirds or more of the underground part is root, the remainder stem ("crown"). Practically all root crops are best adapted to localities with a cool growing season.

References

Goff, E. S.: Vegetables: Garden Beet. 6th Ann. Rept. N. Y. Agr. Exp. Sta., 120–132, 1887.

Kinney, L. F.: Spinach. R. I. Agr. Exp. Sta. Bull. 41: 99–131, 1896.

Pritchard, F. J.: Some Recent Investigations in Sugar-beet Breeding. Bot. Gaz., 62: 425–465, 1916.

Rüggeberg, H.: Beitrage zur Anatomie der Zuckerrübe. Mitt. Kaiser Wilhelms Inst. f. Landw. Bromberg, 4: 399–415, 1912.

Shaw, G. H.: Thrips as Pollinators of Beet Flowers. U. S. Dept. Agr. Bull. 104: 1–12, 1914.

Townsend, C. O., and Rittue, E. C.: The Development of Single-germ Beet Seed. U. S. Dept. Agr Bur. Plant Ind. Bull. 73: 1–23, 1905.

Townsend, C. O.: Single-germ Beet Seed. Jour. Hered., 6: 351–354, 1915.

CHAPTER XXIV

GROSSULARIACEÆ (Gooseberry Family)

There is but one genus—*Ribes*—in this family. It includes the gooseberries and currants.

Stems.—Gooseberries and currants are erect or procumbent shrubs. The stems of gooseberries are armed with spines and prickles, while currants have neither of these present on the stems. The spines and prickles of gooseberries are stem emergences, thus differing from those of certain plums and thornapples, which are reduced branches. Some cultivated varieties of gooseberries are almost thornless. In gooseberries the fruit is borne on one-year-old wood and from spurs (short branches) on older wood. The fruit buds are lateral on the spurs. As a rule, these spurs only bear well for the first two or three years. Black currants produce the most fruit on wood that is one year old, while red and white currants produce fruit most abundantly on spurs that arise from wood two or more years old. When the canes ("stems") reach an age of four or five years their yield decreases, and hence it is the practice to prune out old canes, and keep a supply of new ones coming on. The cutting back of old canes not only induces the formation of fruit spurs, but new canes as well. Propagation of both gooseberries and currants may be made by stem cuttings; gooseberries are also propagated by *layering*, and occasionally from root cuttings. In layering, the branches are bent over and covered with earth; after the buried stems take root, the newly rooted part is severed from the parent plant.

Leaves.—The leaves are alternate, palmately lobed, often resinous-glandular or viscid. Stipules are wanting or present. In all gooseberries and most currants, the leaves are plicate (Fig. 107) in the bud. In a few cases, as the golden currant (*Ribes aureum*), they are convolute (Fig. 107).

Inflorescence and Flowers.—Currants and gooseberries usually have a typical racemose type of inflorescence; rarely the flowers are solitary. Each pedicel is subtended by a

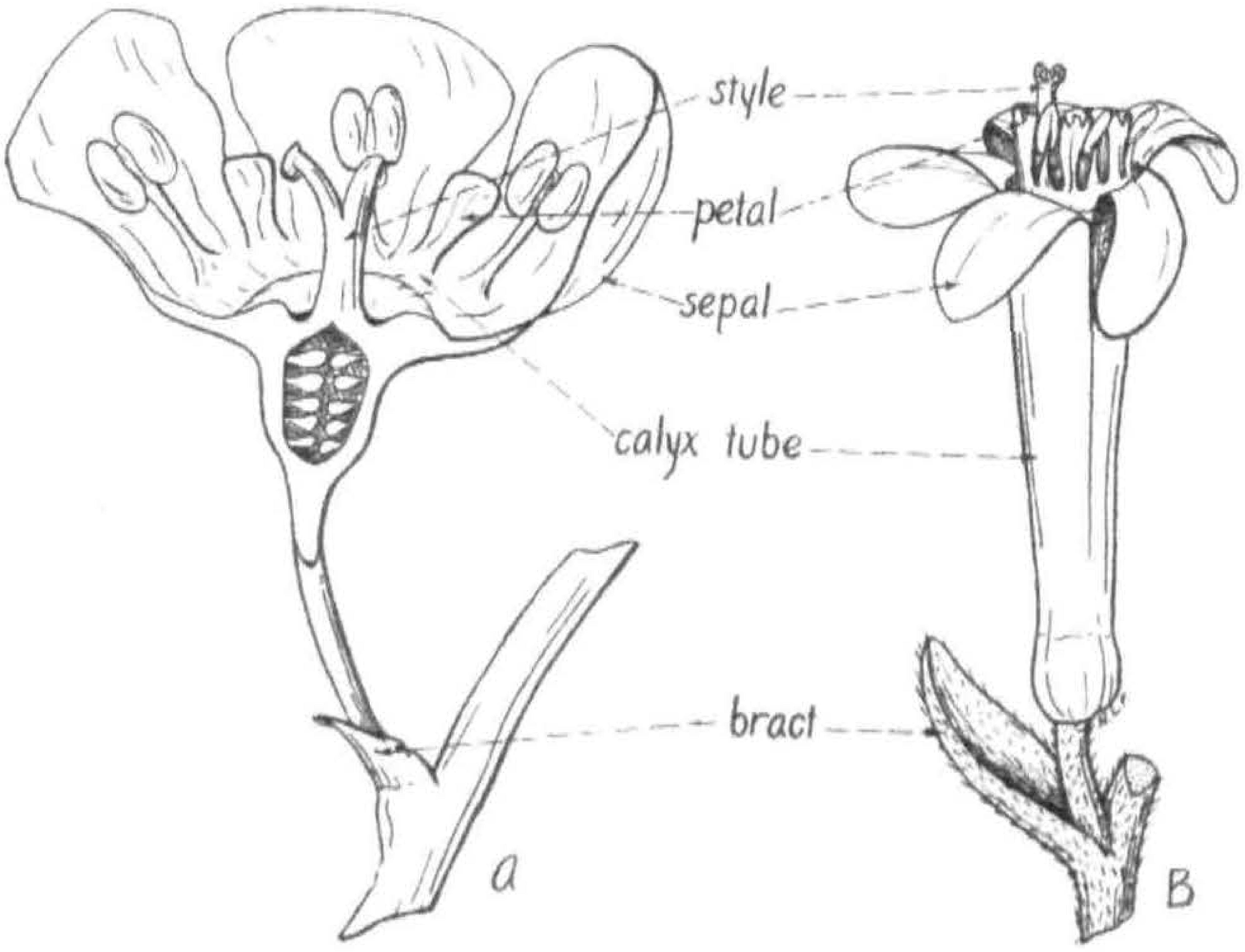


FIG. 133.—*A*, flower of red currant (Ribes rubrum) in lengthwise section; *B*, flower of golden currant (Ribes aureum). The portion designated calyx-tube is in reality toral tube. (*A after Sargent.*)

bract and usually also bears two bractlets at about the middle. The *flowers* are perfect, regular, with calyx and corolla both present and well differentiated (Fig. 133). The receptacle (torus) is cup-shaped and surrounds the carpels (Fig. 134). The *calyx* is divided into four or five lobes, often colored. There are four or five very small *petals*, scale-like and alternating with the calyx lobes; the petals are free, and inserted on the throat of the calyx tube. The *stamens* are of the same number as petals, and are usually included, and attached to

the perianth. The inferior *ovary* is one-celled with two parietal placentæ, each bearing numerous ovules; two more or less united styles are present.

Pollination.—Gooseberries and currants are cross-pollinated, for the most part. Insects are the chief agents in pollination.

The Mature Fruit.—The fruit of the currant and gooseberry has been regarded as a berry; that is, a true fruit

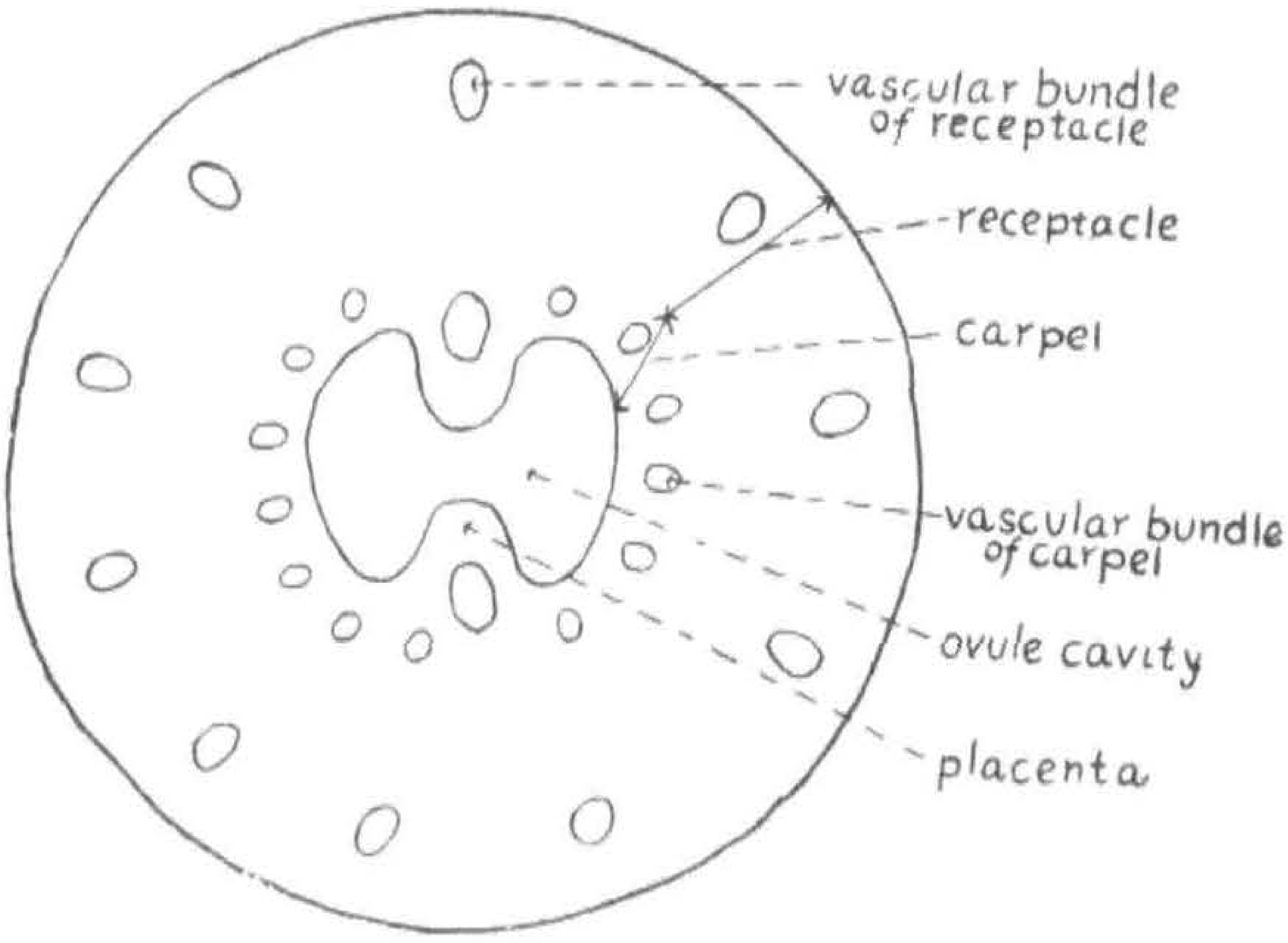


FIG. 134.—Diagrammatic cross-section of Ribes flower prior to fertilization. Note that carpel tissue is surrounded by receptacle tissue, as is evidenced by the two distinct sets of vascular bundles. The fleshy part of the Ribes fruit is thus seen to be composed of receptacle tissue for the most part; hence the fruit is not a berry, morphologically, but rather pome-like. (*Diagram from microscopic section and data furnished by E. J. Kraus.*)

possessing numerous seeds more or less imbedded in a fleshy endocarp and mesocarp. Recent, unpublished work of Kraus establishes the fact that the fruit is in reality pome-like in its structure. A cross-section through the base of the flower or through the fruit shows two distinct sets of vascular bundles (Fig. 134), the outer belonging to the receptacle and leading to the sepals, petals and stamens, the inner to the carpels. Thus it is seen that a large portion of the flesh of the Ribes fruit is toral and not carrpellay. Toral

or receptacle tissue and carpellary tissue imperceptibly grade into each other.

Seeds.—The seeds are small, and slightly flattened on one side. The outer layer of the seed coat is comparatively thick and gelatinous and the inner layer is thin. There is an abundance of endosperm. A minute embryo occurs at the base of the seed.

Geographical.—There are about 100 species of the genus *Ribes*. These are, for the most part, natives of temperate Europe, Asia, North America and the Andes of South America.

KEY TO IMPORTANT SPECIES OF GENUS RIBES

Stems with one to three thorns below the clusters of leaves, often with numerous scattered prickles on the branches, sometimes upon the fruit also. Leaves plaited in the bud (Fig. 107) (Gooseberries).
- Fruit unarmed and smooth; spines on the branches generally solitary (sometimes triple) and slender. *R. oxyacanthoides* (common gooseberry).
- Fruit armed with prickles, or rough and glandular-hairy; spines on the branches usually three together, stout. *R. grossularia* (European gooseberry).

Thornless and prickleless; leaves plaited in bud (Fig. 107); racemes few- to many-flowered (Currants).
- Torus dilated immediately above the ovary.
  - Leaves without resinous dots beneath; fruit red or light. *R. rubrum* (garden currant).
  - Leaves with resinous dots beneath; fruit black. *R. nigrum* (European black currant).
- Torus prolonged above the ovary into a campanulate, cylindrical tube. *R. americanum* (American black currant).

Thornless and prickleless; leaves convolute in the bud (Fig. 107); racemes several flowered; torus above much elongated, bright yellow. *R. aureum* (Missouri, flowering, golden, or Buffalo currant).

CURRANTS

Species.—There are four principal species of currants in American currant culture.

(1) *Ribes rubrum* (*R. vulgare*) includes all our red and white varieties, and is the most important species commercially. The leaves are hairy at first, but become smooth with

age. The small, greenish-yellow or purplish flowers are in drooping racemes. The fruit varies in color; it may be bright red, yellowish, white, or striped. This species is found growing wild from New England to Minnesota and northward; also in Europe and Asia. Commercially, its culture is restricted to northern latitudes. Important varieties are Victoria, Red Dutch, Cherry, Versaillaise, Fay, Prince Albert, and White Grape.

(2) *Ribes nigrum*, the European black currant, is but little cultivated in America. It differs from the preceding in several respects: the lower surfaces of leaves are covered with yellow, resinous dots, and the fruit is black. The greenish-white flowers are in drooping racemes, and the fruit and toral tube are both hairy and resinous-dotted. This currant is a native of middle and northeast Europe, through northern Asia to Manchuria and northern China.

(3) *Ribes americanum*, the native wild black currant of America, is not cultivated to any extent. The plant has a spreading habit. As in the European black currant, the lower surfaces of leaves are resinous-dotted, and the fruit is black in color, but it differs, from the European species in that the toral tube and fruit are not resinous. It is distributed from Nova Scotia and New England south to Virginia and westward to Colorado and Manitoba.

(4) *Ribes aureum* is the chief American flowering currant. It is cultivated principally as an ornamental shrub, but also for its fruit. The wedge-shaped leaves are three-lobed, smooth, and resinous when young. The short inflorescence is very leafy. The most characteristic feature of the plant is its flowers (Fig. 129, B) which have a long, tubular, yellow toral tube, and small reddish petals. The fruit is dark brown or black. The species is native to the Mississippi Valley, and westward to the Rocky Mountains. Important varieties are Crandall, Deseret and Jelly.

Uses.—Currants are made use of for jelly, pies, sauce, and wine.

GOOSEBERRIES

Species.—The cultivated gooseberries belong to two species: *Ribes grossularia*, of Europe and *Ribes oxyacanthoides* (*R. hirtellum*), of America. European gooseberries, as compared with American sorts, are less productive, less hardy, not so easily propagated by cuttings, have a thicker skin, a poorer quality of fruit and are less resistant to the common gooseberry mildew (*Sphærotheca mors-uvæ*).

Ribes grossularia.—This is a robust plant, bearing large thorns, usually in threes. The leaves are shining and pubescent. The flowers have a pubescent toral tube and fruit. The large berry is rough, hairy or prickly, red, greenish, or yellowish in color. The species is a native of Europe, northern Africa and western Asia.

Ribes oxyacanthoides.—The American gooseberry is not as robust as the preceding. The thorns, sometimes in threes, sometimes single, are much more slender, and in some varieties may be entirely wanting. The leaves are shining and finely hairy. The greenish or purplish flowers have a smooth or hairy toral tube and a smooth fruit. The small berry is perfectly smooth, and reddish in color. *Ribes oxyacanthoides* grows from Newfoundland to New Jersey and westward to the Rocky Mountains. Important varieties are Downing, Pale Red, Red Jacket, Champion and Pearl. There are hybrids between the American and European species.

Uses.—Gooseberries are used either green or ripe. They are made into pies, jelly, wine, and stewed or canned.

CHAPTER XXV

CRUCIFERÆ (Mustard Family)

This family is of world-wide distribution. There are in the neighborhood of 2,000 species in 180 genera. The largest number of genera and species is found in southern Europe and Asia Minor. They are found from low to high latitudes and from low to high altitudes.

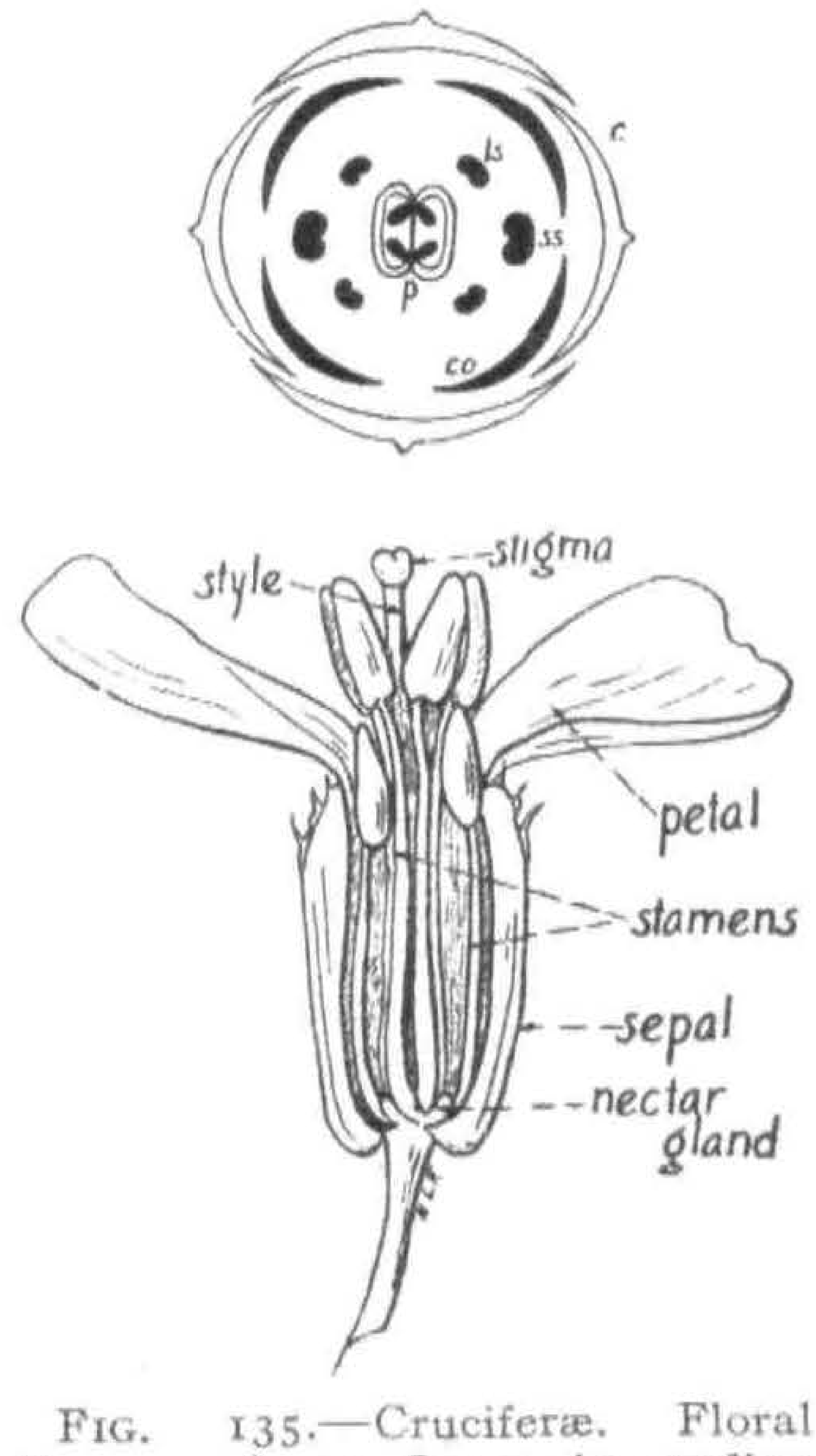


FIG. 135.—Cruciferæ. Floral diagram above; flower in median longitudinal section below.

Many of the genera yield crop plants, such as cabbage, turnip, rutabaga, rape, black mustard, white mustard, radish, water cress and horse radish, while a number of genera include pernicious weeds, such as penny cress, wild mustard or charlock, shepherd's purse, false flax, and tansy mustard.

Stems, Leaves.—Most mustards are herbaceous; a few are woody. The sap is usually watery, and acrid. The *leaves* are alternate, simple, and variously lobed or dissected. The stipules are wanting.

Inflorescence and Flowers.—The predominant type of *inflorescence* is a terminal raceme; rarely the flowers are solitary at the end of a scape. The mustard *flower* is characteristic (Fig. 135). It is perfect and regular with four

sepals, four petals, six stamens (two short and four long), and a two-celled ovary. The four *sepals* are entirely distinct, but often overlapping; the two outer are narrow, and

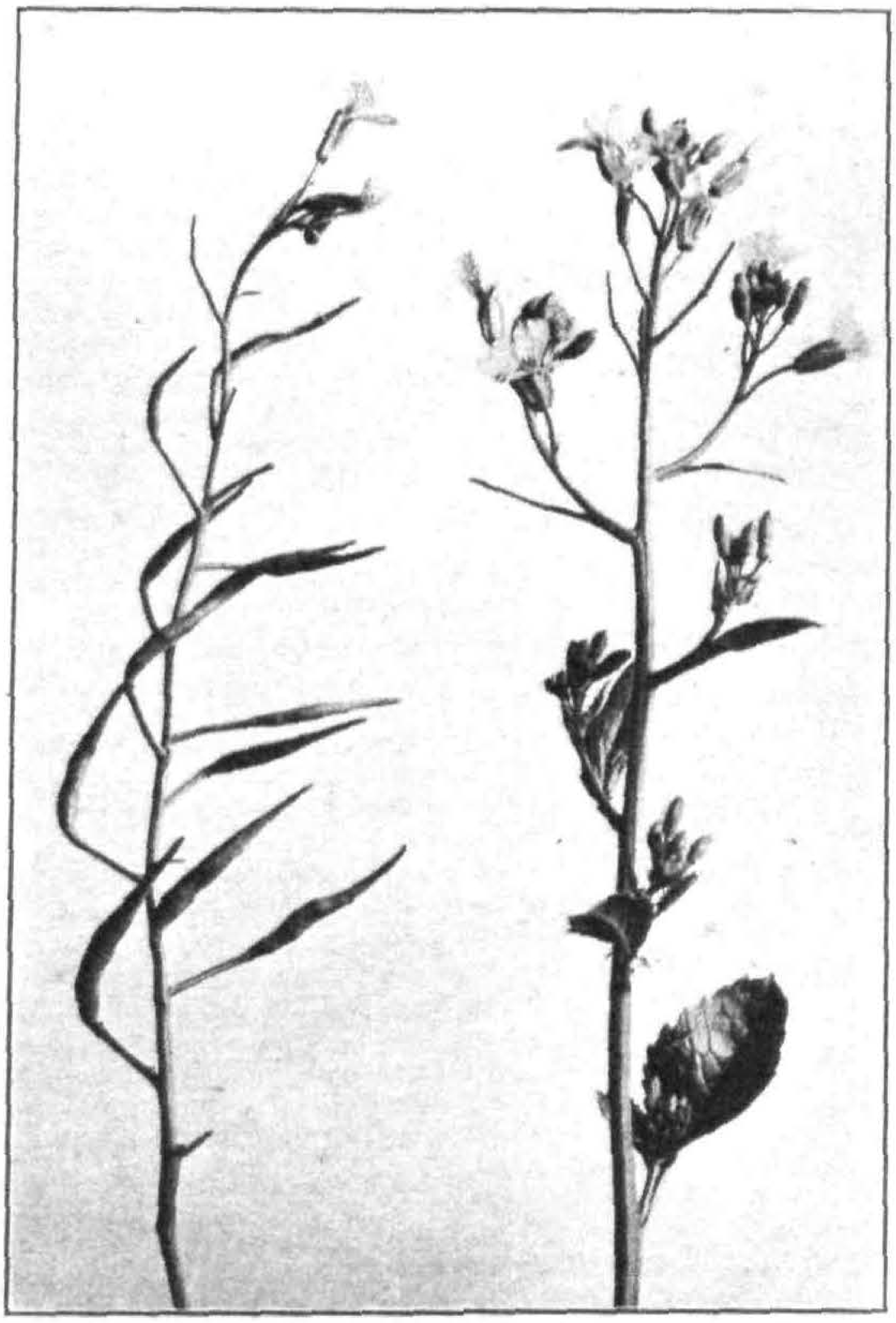


FIG. 136.—Common garden radish (Raphanus sativus). In flower, on right; and in fruit, on left. Note the characteristic racemose inflorescence with flowers at the apex and fruit at the base.

the two inner may be narrow also, but often are distinguished from the outer by being concave or saccate at the base; they are in two distinct whorls. The four *petals* are so arranged that when one looks at the face of the flower, it has the

appearance of a Greek cross, hence the name Cruciferæ (Latin, *crux*, cross, + *fera*, to bear). The petals, as a rule, are clawed, that is, have a narrow or stalk-like base at the tip of which is a broader blade; they are similar as to size and shape. Nectar glands are frequently found at the base of petals. The six *stamens* are in two whorls, the outer two opposite each other and opposite the two sepals of the inner whorl, and with short filaments, the inner four stamens opposite the petals and with long filaments; the anthers are two-loculed (rarely one), and longitudinally dehiscent. The single *pistil* is superior, usually sessile, compound, and has a single style with a more or less two-lobed or disk-shaped stigma; the ovules are attached to two parietal placentas, which are connected by a "false" partition, an outgrowth of the placentas themselves.

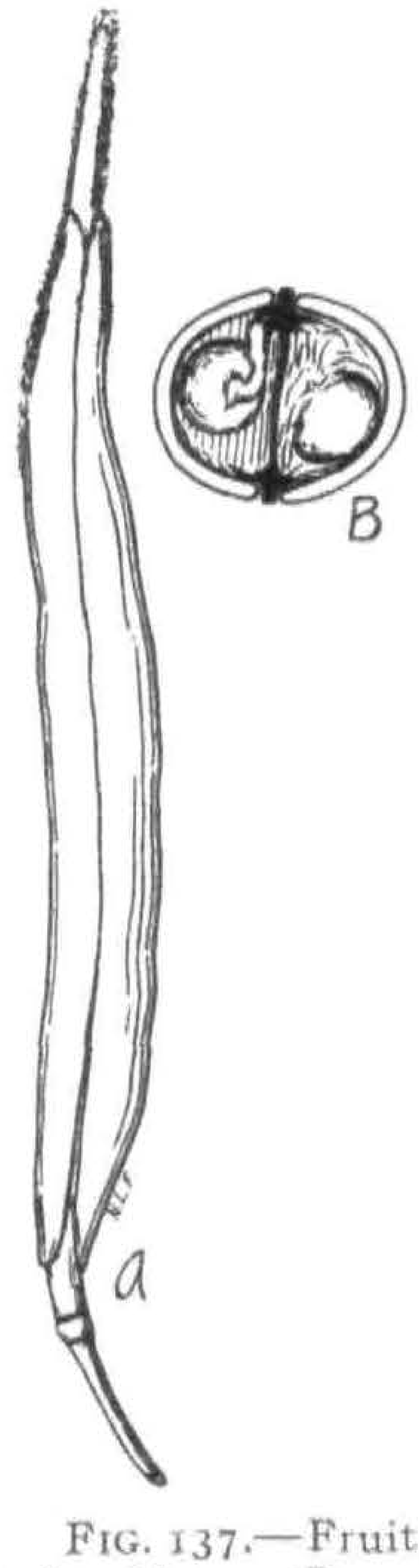


FIG. 137.—Fruit of cabbage (Brassica oleracea capitata). *A*, external; *B*, cross-section.

Fruit.—The ovary develops into a pod-like *fruit* (Fig. 137), which is termed a *silique* (*Brassica*) when long and slender, and a *silicle* (*Bursa*) when short and broad. The sides (valves) of the fruit separate at dehiscence, leaving the two placentas and false partition. In a few genera (*Raphanus*, radish), the fruit is indehiscent.

Seeds.—The *seeds* are usually many, attached to both sides of the partition, and have a mucilaginous testa; the endosperm is lacking; cotyledons are incumbent (with their back against the hypocotyl), accumbent (margins folded against the hypocotyl), or conduplicate (folded upon themselves lengthwise).

The seeds of mustards, like those of grasses and composites, are short-lived, as compared with those of the mallow family, potato family and pea family. Longevity of seeds is due to a number of factors, chief of which is impermeability of the seed coats to water and oxygen. Seeds with permeable coats are more sensitive to moisture and temperature changes than are those with impermeable ones. When moisture is absorbed by the seed its rate of respiration is increased, and hence its vitality reduced. This may be an important factor in shortening the life of the seed.

Closely Related Families.—Members of the mustard family may be mistaken for those of the poppy family (*Papaveraceæ*) or caper family (*Capparidaceæ*), both of which are closely related. The poppies have perfect flowers usually with two early deciduous sepals, while capers are distinguished from mustards by the six approximately equal stamens and by the one-celled capsule.

Key to Principal Genera

Pod indehiscent, *Raphanus* (radish).
Pod dehiscent into two valves.
  Pod a silique, at least twice as long as wide.
    Leaves dissected, *Sophia* (tansy mustard).
    Leaves broadly-lobed.
      Silique beaked by a persistent style; seeds in one row, *Brassica* (cabbage, turnip, rutabaga, rape, black mustard and white mustard).
      Silique beakless; seeds in two rows, *Radicula* (water cress and horse radish).
  Pod rarely more than twice as long as broad.
      Silique not flattened, nearly circular in cross-section, *Camelina* (false flax).
      Silique flattened.
        Silique elliptic or oval, *Lepidium* (penny cress).
        Silique triangular-obovate or obcordate.
          Basal (radical) leaves pinnatifid, *Capsella* (shepherd's purse).
          Basal leaves entire or merely toothed, *Thlaspi* (penny cress).

BRASSICA

Generic Description.—This genus includes annual (black mustard), biennial (turnip), or perennial (cabbages under their natural conditions) herbs. The root system may be

fleshy (turnip), or rather woody and solid (cabbages). The basal (radical) *leaves* are frequently pinnatifid, while those of the stem (cauline) are entire, dentate, or broadly lobed. The large, yellow *flowers* are in elongated racemes. The sepals, petals, and stamens are as described for the family. The *silique* (Fig. 137) is elongated, sessile, terete or four-sided, and tipped with an indehiscent, conic, usually one-seeded beak; the valves are convex, one- to three-nerved, the lateral ones often flexuous; the septum (partition) is membranous or spongy; at the tip of the silique is a short or elongated style tipped by a truncate or two-lobed stigma. The *seeds* are in one row in each cell.

Pollination.—Representatives of the genus are for the most part insect pollinated. It appears that both self- and cross-pollination takes place.

Seedling.—At germination of the seed, the cotyledons are brought above ground. In all representatives of the genus, the cotyledons are emarginate (notched at apex), unequal in size, and three-nerved at the base.

Geographical.—There are about 80 species in the genus *Brassica*, chiefly occurring about the Mediterranean region; some are now cultivated, however, in boreal and subtropical regions of Europe, Asia, Africa, and North and South America. None of the *Brassicas* are native of America or Australia.

KEY TO PRINCIPAL SPECIES OF GENUS BRASSICA

Leaves of flowering stem not clasping; annuals; sepals spreading.
- Seeds small, reddish-brown; valves of silique one-nerved, *B. nigra* (black mustard).
- Seeds large, pale yellow; valves of silique three-nerved, *B. alba* (white mustard).

Leaves of flowering stem somewhat clasping; biennials; sepals erect.
- Roots swollen and fleshy.
  - Young leaves glaucous; a distinct short stem on upper part of root, *B. campestris* (rutabaga or Swede turnip).
  - Young leaves grass-green; no distinct short stem on upper part of root, *B. rapa* (turnip).
- Roots not fleshy.

Young foliage covered with a few hairs, *B. napus* (rape).
Young foliage smooth, *B. oleracea* (cabbages, etc.).

BRASSICA OLERACEA (Cabbages, etc.)

Wild Cabbage.—This is the parent of the various forms of cultivated cabbage. It grows wild along the coasts of

FIG. 138.—Wild cabbage. (*After Bailey.*)

England and Wales, Channel Island, and western and southern Europe. It is a stout perennial or biennial from a tough and woody root. The stem is branching and attains a height of 1 to 2 feet (Fig. 138). The lower leaves are stalked, lyrate or pinnatifid, entire, and broad, while the upper ones are sessile and much smaller. There is no tendency to form heads in the wild form. The flowers are in elongated racemes and are rather large, about ¾ to 1 inch in diameter, and of a pale yellow color. The fruit is a smooth silique often 3 or 4 inches long.

Cultivated Types of Brassica oleracea.—A number of types have arisen, probably as mutants, from the native wild cabbage. The modifications concern the stem as in kohlrabi, the foliage as in kale, head cabbage, and Brussels sprouts, and inflorescence, as in broccoli and cauliflower. The characteristic differences between these are shown in the following key:

KEY TO CULTIVATED TYPES OF BRASSICA OLERACEA

Stem of first year elongated.
  Stem branched and leafy; plant much resembling wild cabbage (Fig. 139), *B. oleracea var. acephala* (kales and collard).
  Stem unbranched, the axillary buds developing into small heads (Fig. 140), *B. oleracea var. gemmifera* (Brussels sprouts).

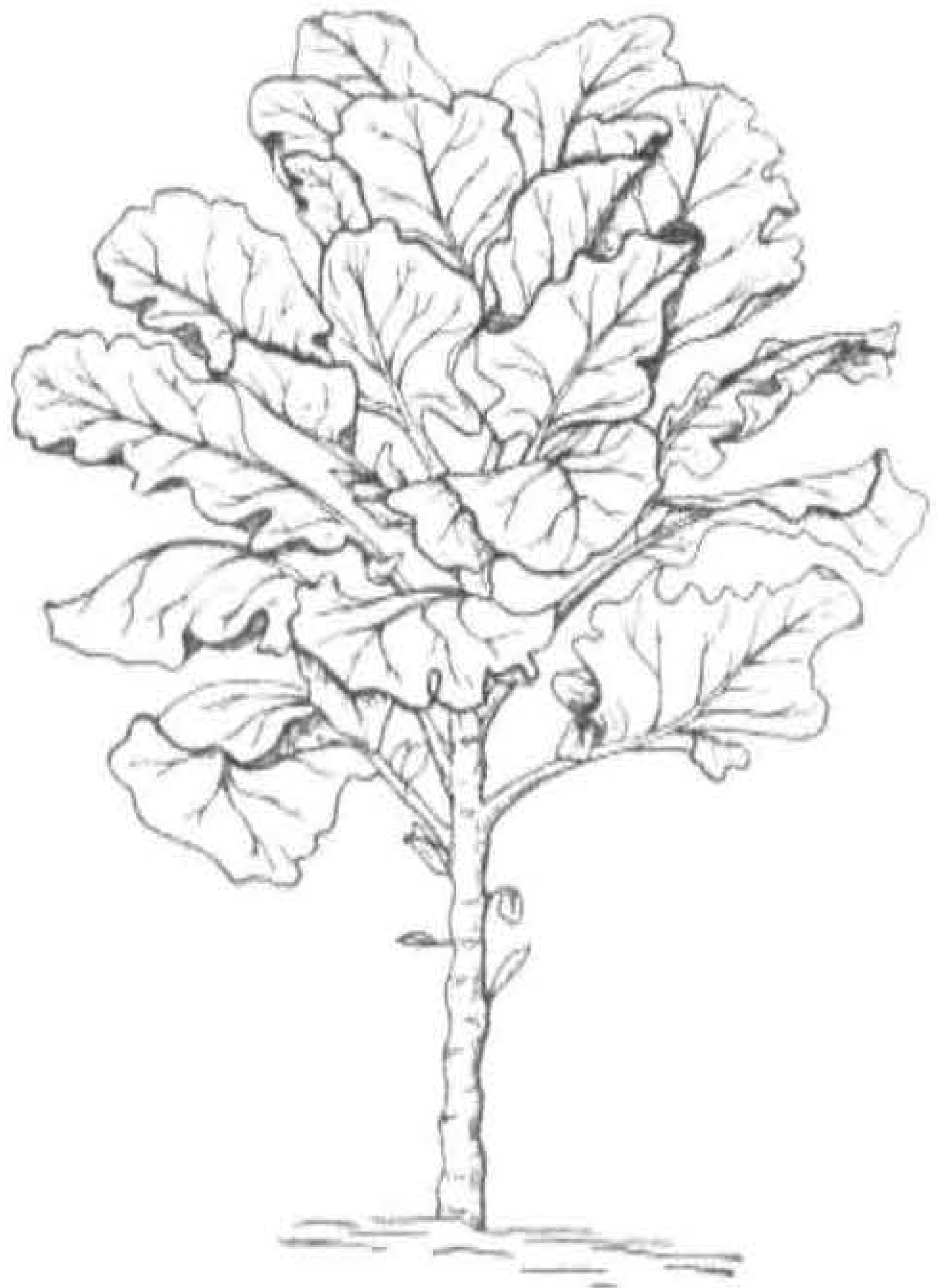


FIG. 139.—Kale (Brassica oleracea acephala). (*After Vilmorin.*)

FIG. 140.—Brussels sprouts (Brassica oleracea gemmifera).

Stem of first year short.
  First-year stem forming a "head" (Fig. 141), *B. oleracea var. capitata* (common cabbage).
  First-year stem not forming a "head."
    Turnip-like stem which stands mostly above ground. (Fig. 142), *B. oleracea var. caulo-rapa* (kohlrabi).
    Stem not turnip-like, leafy below, inflorescence partially developing first season (Fig. 143), *B. oleracea var. botrytis* (cauliflower, broccoli).

BRASSICA OLERACEA VAR. ACEPHALA (Fig. 139)

The members of this group resemble very much the wild form of cabbage. The terminal and lateral buds elongate during the first season, giving the plant a branching habit.

Forms of this variety are known as kale, borecole, marrow cabbage, or collard. Collards are grown in the South particularly. This southern form is known as the Georgia collard. Marrow cabbage or marrow kale is a broad-leaved form. There are a number of kales with finely dissected leaves; among such are the well-known Scotch kales, rather common market sorts. The tree kales have straight, stiff and strong stems often 3 or 4 feet tall; the dwarf kales are lower and close to the ground. Dwarf Green Scotch Kale is the most common sort grown in the Norfolk truck-gardening area. Thousand-headed kale is a very large, highly branching form. The large-leaved kales, such as marrow kale and thousand-headed kale, are used as stock food. The finer-leaved varieties are used as a boiled green vegetable.

Unlike their close relatives, Brussels sprouts, head cabbage, kohlrabi and cauliflower, kale and collard will endure the heat and drought of summer, and kale, at least, will stand considerable freezing.

BRASSICA OLERACEA VAR. GEMMIFERA (Brussels sprouts) (Fig. 140)

Here belong those cabbages in which the axillary buds develop into small heads or "sprouts." These are formed in the axils of leaves. The main stem is elongated and unbranched. The first "sprouts" to appear are those at the base of the stem, subsequent ones appearing in order from below upwards, almost to the top of the stem. Brussels sprouts resemble the kales except that the axillary buds, instead of developing into side branches, do not elongate but develop into "heads," which are in reality specialized buds, usually 1 to 2 inches in diameter.

Types.—There are two general types of this plant: tall Brussels sprouts and dwarf Brussels sprouts. The former

type grows to a height of 2 to 3 feet, is rather slender, and the leaves and "sprouts" are comparatively far apart. It is not grown to any extent in this country; dwarf varieties are preferred here. These latter seldom exceed 2 feet in height; they have a stout stem upon which the leaves and "sprouts" are crowded. As a rule, the leaves of the dwarf type are more crimped than those of the tall type. All the types are cool season plants.

Uses.—Brussels sprouts are much more tender than common head cabbage. The smaller "sprouts" are the most desirable. They are cooked in a manner similar to cabbage.

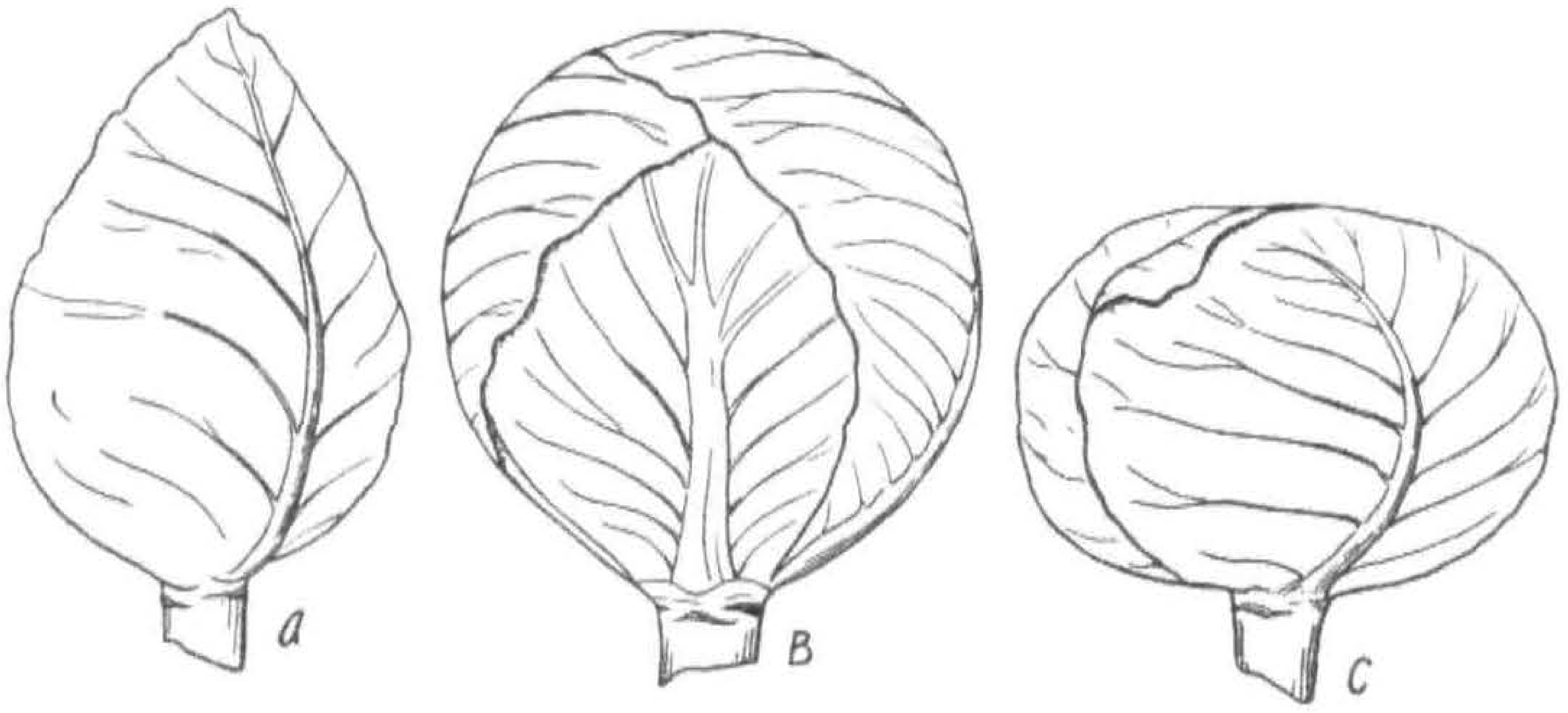


FIG. 141.—Common head cabbage (Brassica oleracea capitata). Three common types of heads: *A*, pointed or oblong; *B*, ballhead; *C*, drumhead.

BRASSICA OLERACEA VAR. CAPITATA (Common Head Cabbage) (Fig. 141)

The common head cabbage produces, the first year, a short stem upon which are found numerous, thick, overlapping, smooth leaves, the whole forming the "head." A longitudinal section of a cabbage head shows the terminal bud, and, in some instances, rather well-developed axillary ones.

Types.—There are numerous varieties of cabbages. They have been grouped into a number of different types. These types vary as to color, size, and shape of head and leaves,

texture of leaves, length of stalk, earliness, etc. As grouped here, the types may be distinguished as follows:

KEY TO TYPES OF COMMON HEAD CABBAGE

Leaves smooth, not crimped or curled.
  Leaves dark purple or red, *Red cabbages.*
  Leaves glaucous-green.
    Heads cone-shaped, longer than broad (Fig. 141, A), *Winningstadt and Wakefield cabbages.*
    Heads spherical (Fig. 141, B), *Danish Ball Head cabbages.*
    Heads flat, broader than long (Fig. 141, C), *Flat Dutch or Drumhead cabbages.*
Leaves crimped or curled, *Savoy cabbages.*

The red varieties of cabbage are valued for pickling and slaw. The Wakefields are the ones most extensively grown in trucking districts. There are two main types of Wakefields: True Jersey Wakefield which has small heads pointed at the tip, and Charleston Wakefield, with a head broader, flatter and more obtuse-pointed. Danish Ball Head cabbages are most used for storage purposes. The Savoy cabbages, especially when slightly frosted, are known for their very excellent flavor.

Uses.—Cabbage is grown as a market-garden, truck and farm crop, and is best adapted to a cool climate. As a human food, it is most generally boiled or used as slaw. *Sauerkraut* is cabbage cut up into very fine pieces and allowed to ferment in a brine made of its own juice with salt. The sour taste is due to the presence of lactic acid, formed by the action of lactic-acid species of bacteria on the sugar in the cabbage juice. Ordinarily there is a maximum of about 1 per cent. of lactic acid, the presence of which prevents putrefaction of the sauerkraut. Among other organisms, yeast is universally present in the fermenting cabbage. Cabbages are also used quite extensively for pickling, and as a food for stock and chickens.

BRASSICA OLERACEA VAR. CAULO-RAPA
(Kohlrabi) (Fig. 142)

The stem is short, much thickened, fleshy, and stands out of the ground. The fleshy part comes from the stem above the cotyledons, hence is not root. The swelling begins at the ground line; there is formed a large, spherical body upon which are very prominent, broad leaf scars.

As to color there are two principal types: Those with white "balls" or stems (White Vienna Erfurt); and those with purple "balls" (Purple Vienna).

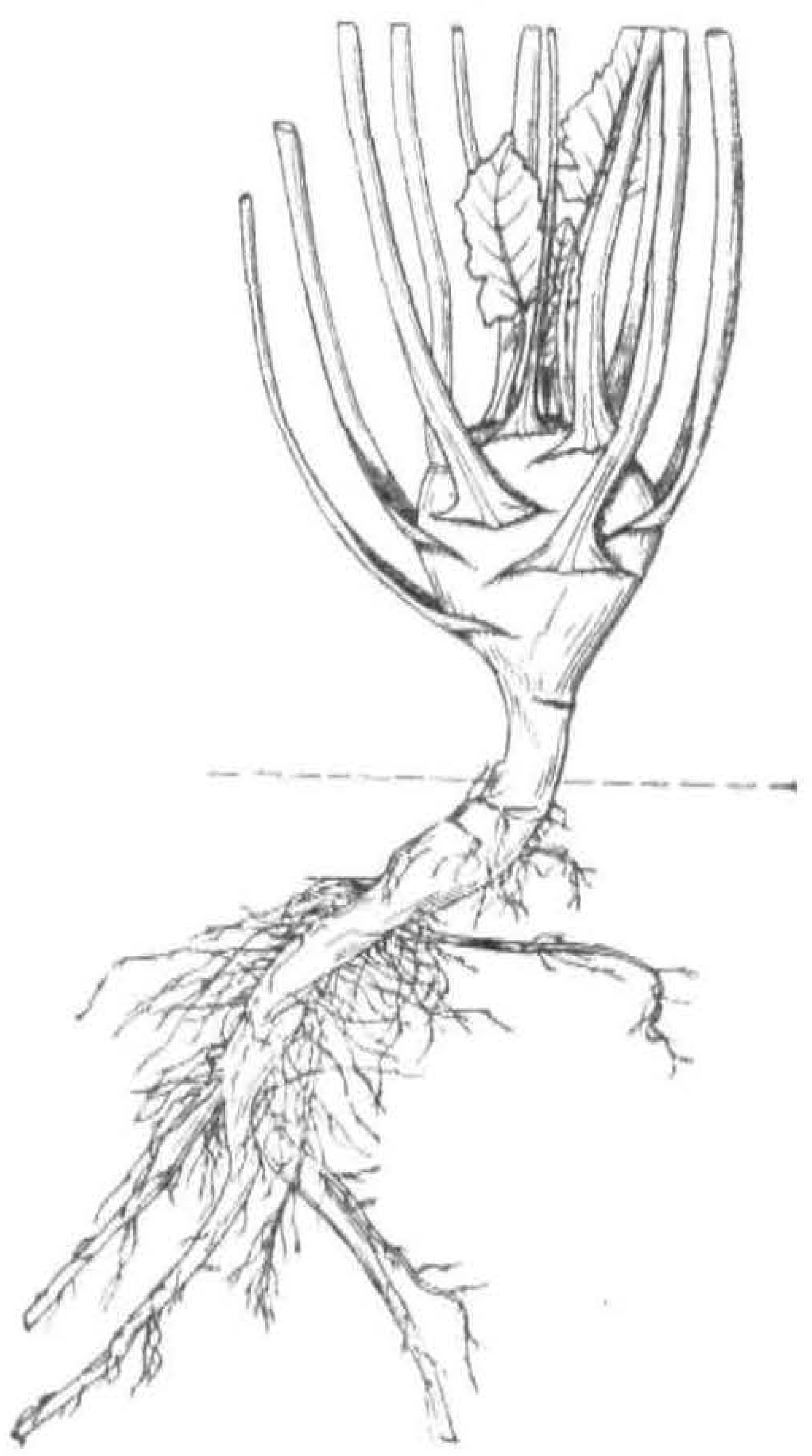


FIG. 142.—Kohlrabi (Brassica oleracea caulo-rapa.)

Kohlrabi is not grown extensively in the United States. It is used particularly by our foreign population, being stewed and eaten like turnips or rutabagas. It is also a valuable stock food; both the stems and leaves are used for this purpose. Kohlrabi is chiefly grown as an early spring crop, less frequently as a fall crop. It does not endure the heat of summer.

BRASSICA OLERACEA VAR. BOTRYTIS
(Cauliflower, Broccoli) (Fig. 143)

Cauliflower and broccoli are types of *Brassica oleracea* in which there is a large "head," (Fig. 143), the edible portion, which consists chiefly of the fleshy peduncles and pedicels, whereas the flower parts are but slightly developed and constitute only a very small part of the edible "curd." Sub-

tending the head are a number of cabbage-like leaves. In growing the vegetable, these basal leaves are tied up about the fleshy, white head to prevent its browning by the sun.

Most varieties of broccoli grow to a larger size than cauliflower, have a larger "head," are hardier, and take

FIG. 143.—Cauliflower (Brassica oleracea botrytis). *A*, entire plant; *B*, portion of "head."

longer to mature. It is necessary to tie the leaves over the head ("curd") in most varieties of cauliflower in order to obtain a pure white product, whereas, in most of the broccoli

varieties, the inner, incurving leaves protect the head, thus eliminating the necessity of tieing.

Cauliflower and broccoli are both cool-season crops.

BRASSICA RAPA (Turnip)

Description.—The common turnip is a biennial. The first year a swollen and fleshy tap root is formed. However, the "turnip" is combined primary root and hypocotyl. The upper portion to which the leaves are attached is stem, while the lower portion to which secondary roots are attached is root.

The *leaves* that arise from the "turnip" the first season are in the form of a rosette. They are oblong to oval, sometimes entire, serrate, or the later ones pinnate or pinnatifid. First-year leaves are grass-green and rough-hairy. The second season, a stem 1 to 3 feet tall is sent up from the terminal bud in the center of the rosette of leaves, which bears alternate, clasping, lanceolate or oblong, entire or dentate, smooth leaves. The flower stem is branching. The *inflorescence* is a raceme. The *flowers* are bright yellow, about ½ inch in diameter and of the characteristic mustard type. The *fruit* is 1½ to 2 inches long, cylindrical, and tipped by a short beak. The *seeds* are reddish brown in color, spherical, and number 15 to 25 in each silique.

Geographical.—The turnip seems to have originated in Europe or Western Asia. By cultivation, it has spread into all temperate regions. The cultivated sorts are grown as cool-season crops.

Types of Turnips.—There are numerous varieties of turnips, varying chiefly as to shape and color of "root" (Fig. 144).

The principal varieties grown in the United States may also be classified as follows (in each division but one or two examples are given):

Flesh white.
  Root entirely white.
    Flat (Early White Flat Dutch Strap-leaved, Extra Early White Milan).
    Spherical (Snowball, White Globe Strap-leaved).
    Oval (White Egg).
    Carrot-shaped (Cow-horn).
  Root purple or red at top, white below.
    Flat (Purple Top Strap-leaved, Extra Early Purple-topped Milan).
    Spherical (Purple Top White Globe).
  Root entirely red (Scarlet Kashmyr).
Flesh yellow.
  Root entirely yellow (Golden Ball).
  Root green at top, yellow below (Amber Globe).
  Root red at top, yellow below (Early Red Top Globe).

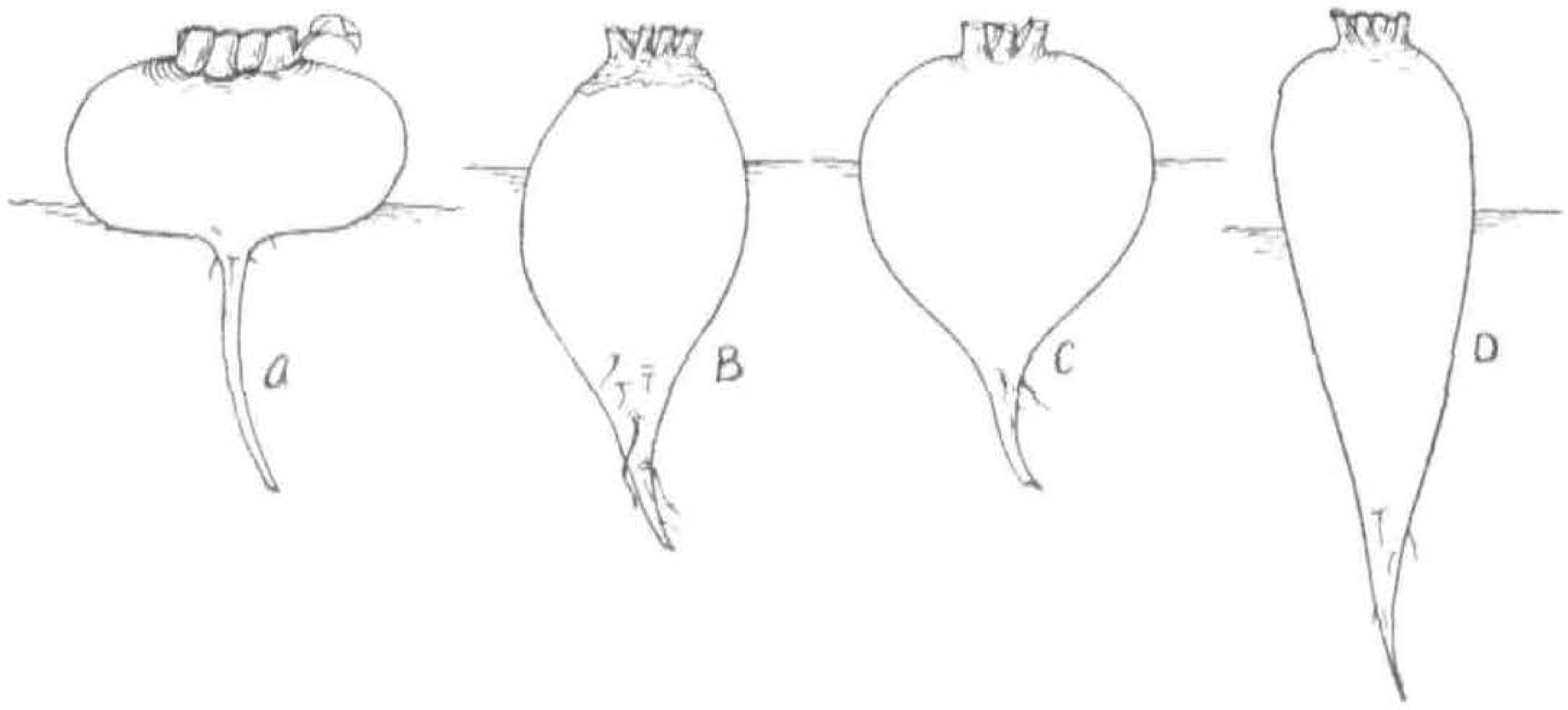


FIG. 144.—Types of turnips (Brassica rapa). *A*, flat; *B*, tankard or spindle; *C*, globe; *D*, long. (*After Percival.*)

Structure and Uses.—It will be recalled that the greater portion of a turnip is tap root. In cross-section, it shows the following layers (Fig. 145):

1. Outer layer or cortex (bark).
2. Cambium.
3. Main flesh of turnip (wood and pith).

In the fleshy root of the turnip, the walls of the cells which make up the wood are not lignified, and hence the tissue is soft, unlike ordinary wood tissue. The medullary rays are very indistinct. Some turnips are coarse in texture and

such are used for stock food. The turnips of finer texture are used as food by man. In the South the variety Seven Top is grown as a green forage and green manure.

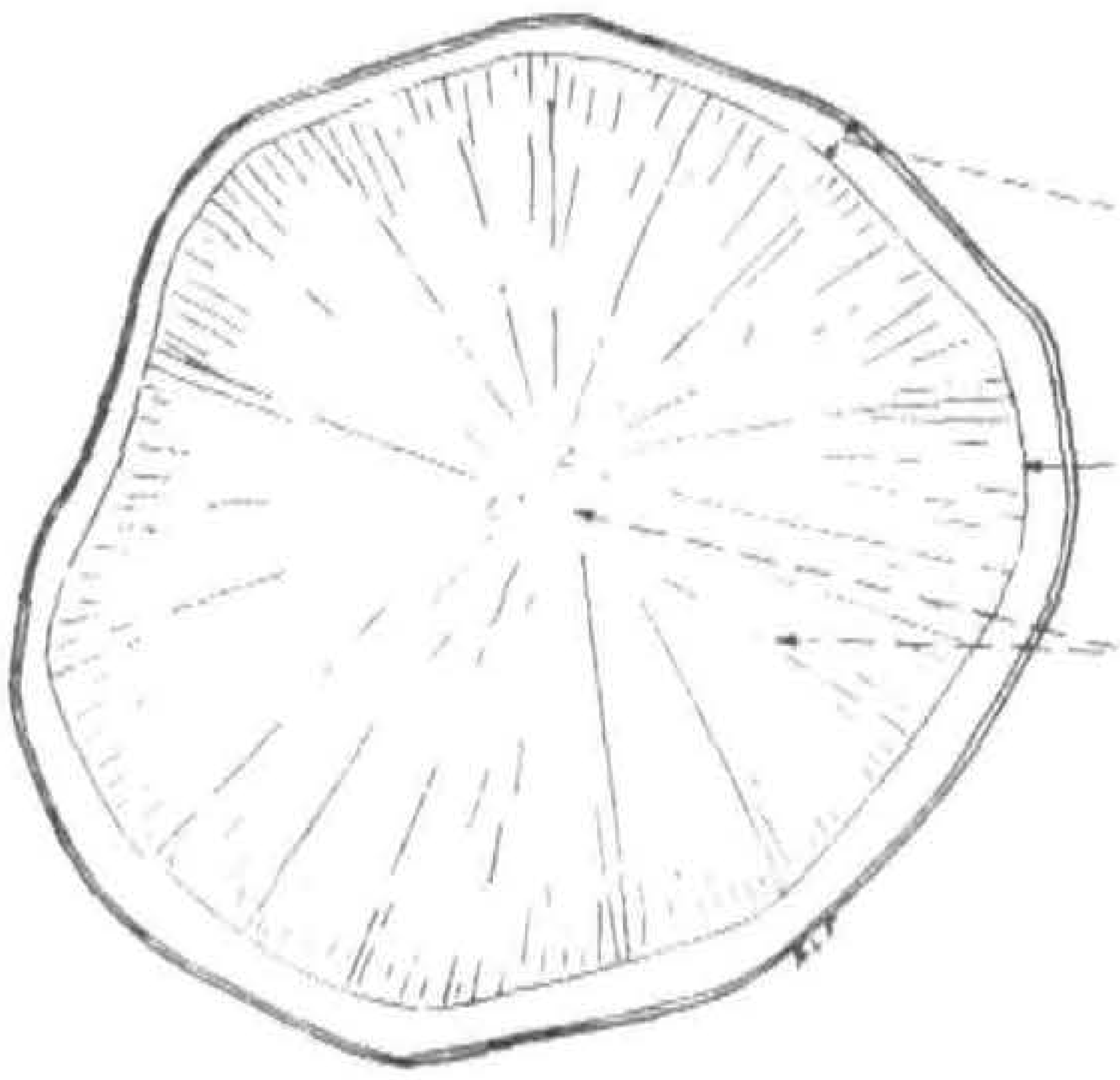


FIG. 145.—Root of turnip (Brassica rapa) in cross-section. Diagrammatic.

BRASSICA CAMPESTRIS (Rutabaga or Swede Turnip) (Fig. 146)

Description.—This species resembles very closely *B. rapa*, the common turnip. Rutabagas or "Swedes," have a short stem or "neck" at the upper part of the vegetable. It is this character which easily distinguishes the rutabaga vegetable from that of turnip. The flesh is solid and yellow or orange in color. The first leaves are bluish white, and all leaves have thick, fleshy petioles. The yellow flowers are larger than those of the turnip, and the claws are longer.

Uses.—Rutabagas or "Swedes" have less water than common turnips. They are commonly grown as a food for stock, but are also eaten in large quantities by man. They develop the sweetness and flavors for which they are so well known only in the Northern States where the nights are cool.

BRASSICA NAPUS (Rape)

Description.—Rape is a biennial plant, growing to a height of 2 to 3 feet. It thrives best in those regions with

cool summers. The stem is branched to a considerable extent. There is no swollen root. The lower leaves are lyrate, the upper ones oval to lanceolate and clasping the stem. The inflorescence is of the typical racemose type. The flowers are bright yellow. The seeds are black or dark purple. The seedlings and young plants resemble those of *B. campestris* (rutabaga).

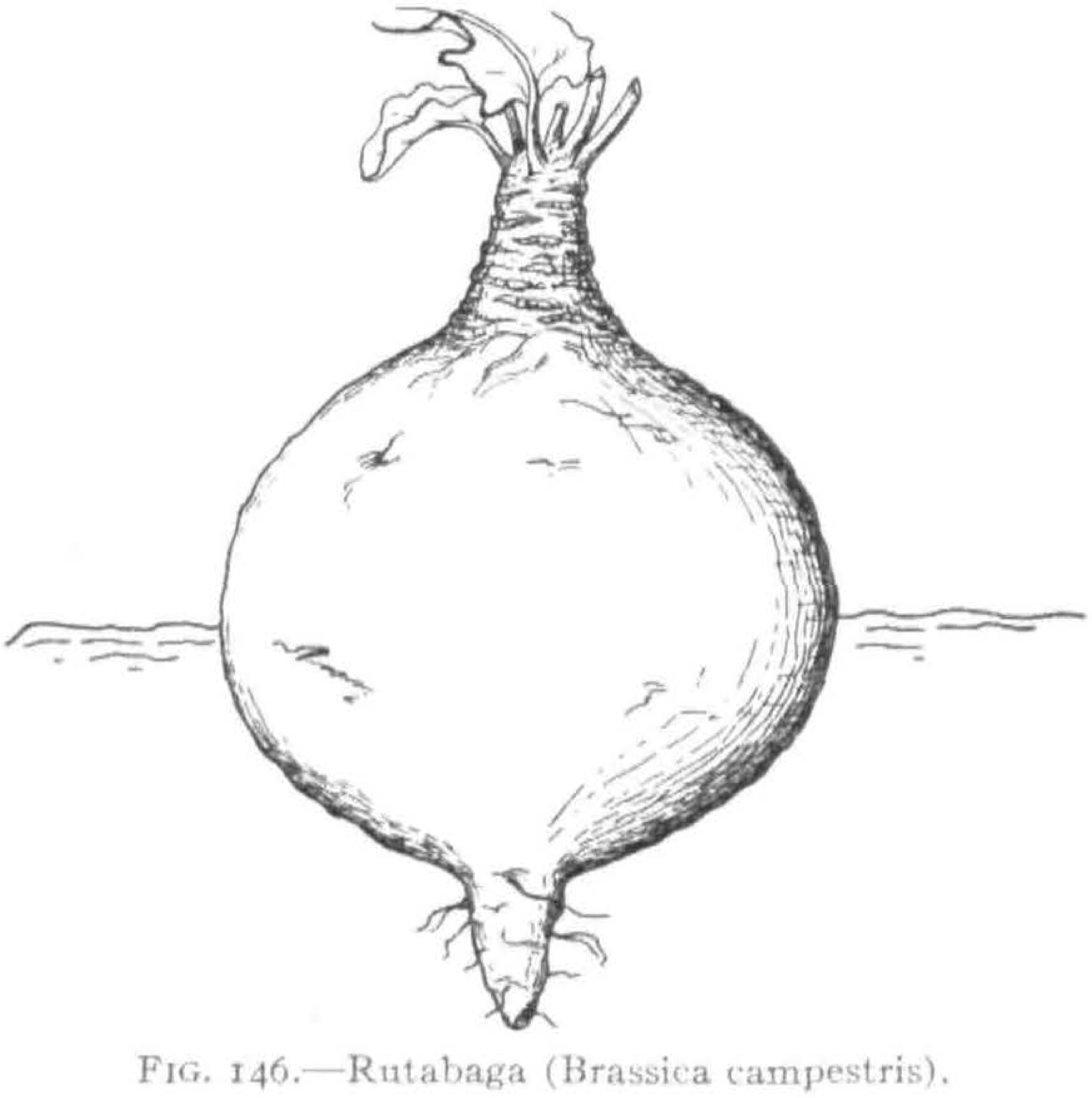


FIG. 146.—Rutabaga (Brassica campestris).

Varieties and Uses.—The principal variety of rape in the United States is Dwarf Essex or English rape. This is a variety used for its green foliage, and hence is treated as an annual. This type of rape is used as a fall pasture for sheep, pigs or cows, as a green manure, and as a soiling crop, catch crop, or cleaning crop. "Rape cake," made from the seeds by expressing the oil, is used as a stock food, and the oil itself is of some value. About 42 per cent. of the seed is composed of rape oil.

BRASSICA NIGRA (Black or Brown Mustard)

Description.—The black mustard is an annual herb 2 to 7 feet tall, and freely branching. The lower *leaves* are hairy and deeply pinnatifid, with one large, terminal lobe and two to four smaller, lateral ones; the lobes are coarsely toothed. The upper leaves have much shorter petioles than the lower, or they are entirely sessile, and the blades are entire and oblong or lanceolate. The *flowers* are bright yellow. The *pods* are slender, four-sided, oppressed against the stem, and measure about ½ inch or more in length. The *seeds* are dark brown.

Black mustard is a native of Europe and Asia. It has become naturalized in this country and has escaped from cultivation, becoming frequently a troublesome weed.

Black mustard resembles charlock (*Brassica arvensis*), one of the worst pests in grain fields of the Middle West. Charlock has long, knotted pods with stout beaks, while the pods of black mustard are short, four-angled, and with short beaks. The pods of white mustard are somewhat bristly. Charlock, black mustard and white mustard are propagated by seeds. In their eradication, no attention needs to be directed toward the starving out of rootstocks, which are so typical of perennial weeds. Every effort is made to prevent them from going to seed. Much success has attended the use of chemical herbicides, chiefly iron sulfate, in eradicating the mustards from grain fields. All grasses are resistant to injury from this spray, but the young mustards, and many other weeds, are quite easily killed by it. This is due to the fact that the spray does not adhere so readily to the smooth grass-leaves as to the mustard leaves; moreover, although the tips of grass leaves are injured, the growing tissue at the leaf base may not be touched by the spray, and hence the recovery is rapid.

Related Species.—It is closely related to the white mustard which is described hereinafter, and to Chinese or Indian mustard (*Brassica juncea*). The latter is adventive from Asia in this country, often a bad weed, and sometimes its leaves are used for "greens." In the Indian mustard, the pods are 1 to 2 inches long, and some of the forms have leaves twice the size of those in the ordinary black or white mustards. The Japanese or pot-herb mustard (*Brassica japonica*) is introduced into the United States. It has thin, soft leaves which are valued as "greens."

Uses.—The plant is used mainly for garnishing, also in salads and in the preparation of meat dressings and sauces. Occasionally it is boiled like spinach. *Table mustard* is the ground seeds of black mustard. The aroma and pungency of mixed mustard (table mustard) does not exist in the seed itself, but is given rise to when the ground seed is mixed with water. This pungent, volatile oil is an allylthiocyanate and is formed by the action of a specific enzyme, myrosin, upon potassium myronate—a glucoside present in the seed.

BRASSICA ALBA (White Mustard)

This species has characteristics very similar to those of black mustard. It is distinguished from the latter chiefly by its lighter colored bristly pods, and its lighter colored and larger seeds.

The plant is a native of Europe, Asia and northern Africa. It is used similarly to the black mustard, and in addition is sometimes used as a green manure. The mixed mustard from this species is less pungent than that from *B. nigra*.

RAPHANUS SATIVUS (Garden Radish)

The common garden radish is an annual or biennial herb. It may produce fruit the same year, when planted early in the season, while, if planted late, it produces a fleshy tap root the first year, which may be kept over the winter until the next year, when it produces fruit.

Root.—The radish vegetable is mainly a *tap root*, varying in size, shape, and color. At the top is a short hypocotyl

(stem). The laterals from the tap root are few in number and very slender.

Stem.—From the hypocotyl or crown of the radish, there first appears a rosette of leaves, and later an erect, freely branching *stem*, 1 to 2½ feet tall. This stem may be sparsely pubescent with stiff hairs, especially below, or rarely glabrous throughout.

Leaves.—The basal and lower *leaves* are deeply lyrate-pinnatifid, 4 to 8 inches long; the upper leaves are few, small, and oblong.

Inflorescence and Flowers.—The *inflorescence* is an elongated raceme (Fig. 136). The *flowers* are of the typical mustard type; the sepals are erect and sac-like at the base; the petals rose-lilac or white.

Fruit.—The pods are 1 to 1½ inches long, two- to three-seeded, fleshy, or corky with a spongy tissue separating the seeds; the pods are not longitudinally grooved or prominently constricted; they are capped by a long conic beak which may equal or exceed the pod itself.

Seeds and Seedling.—The *seeds* are small and of a yellowish color; on one side, when viewed with a hand lens, may be seen a small spot, in reality double, made up of the hilum and micropyle. Endosperm is absent. The cotyledon leaves are persistent until the root becomes of considerable size and may be seen at the crown of the radish, lying flat against the root. Each cotyledon leaf is oblong in outline and broadly notched at the tip.

Geographical Distribution and Origin.—The common radish is found growing wild in the temperate regions of the Old World. It was introduced into this country by the earlier settlers and here, as wherever it is planted, has escaped from gardens, becoming in many instances a rather common wayside plant. Radishes that run wild in this manner produce a root that is slender and woody, possibly

reverting to the type from which it came. Carriere held the opinion that our common garden radish has sprung from *Raphanus raphanistrum*, the wild radish or white charlock, and a common weed throughout Europe, and also adventive in the United States. He bases his opinion on his own experiments which in brief were as follows: The seeds of *Raphanus raphanistrum*, which has very woody and slender roots, were planted and after five years of care there was developed a type of root which was fleshy, large, and varying in form and color. The roots developed had the flavor of our garden radishes and were edible. In spite of the experiments of Carriere, many botanists believe that white charlock is not the projenitor of the radish. For example, it is known that the garden radish long ago was a common plant in India, China, and Japan. But *Raphanus raphanistrum* is not found in these countries, and furthermore, the main movement of cultivated plants has not been from Europe to Asia, but from the orient to the occident.

Closely Related Species.—*Raphanus raphanistrum*, white charlock, mentioned above, may be quite easily mistaken for the common radish, especially when the latter has run wild. White charlock, however, has yellowish flowers turning white or purplish, and a silique which is much more conspicuously jointed and longitudinally grooved than that of common radish.

Raphanus sativus caudatus, the rat-tailed radish, an annual herb native to South Asia, has a slender, twisted pod, 8 to 10 inches long, which thus differs from the short, thick ones of common radish. These pods form the edible portion of the plant.

Types of Radishes.—As to seasonal development, there are three groups of radishes, as follows:

1. *Early or Forcing Radishes.*—A *forcing crop* is one grown out of season, and out of its natural environment. Hot beds, cold frames and greenhouses are the forcing structures in use. The chief crops forced besides radishes are lettuce, tomatoes, cucumbers, cauliflowers and beans. Early or forcing radishes reach an edible size very soon, often in from

twenty to thirty days. In this group, belong such varieties as French Breakfast, Early Scarlet Turnip, Scarlet Globe, Long Scarlet Short Top, and White "Icicle."

2. *Summer Radishes.*—The roots of this group are slower in maturing, requiring from six to eight weeks to reach a marketable size, and are larger than those of the first group. Here belong such varieties as Long White Vienna, Chartiers, White Strasburg, Stuttgart.

3. *Winter Radishes.*—These have a compact and firm flesh and keep well through the winter. The roots require several months to reach maturity, often attaining a large size. Common winter varieties are Black Spanish, Sakurajima or Japanese radish, and White Chinese.

As to shape, radishes may be classified as follows (Fig. 147):

1. Round or turnip-shaped (Early Scarlet Turnip, Scarlet Globe, Scarlet Gem).

2. Olive or oval-shaped (intermediates) (French Breakfast, Early Scarlet Olive-shaped, Black Spanish).

3. Half-long (Scarlet Half-long, French, Half-long Deep Scarlet).

4. Long (Vienna, Chartier, Long Scarlet, White "Icicle").

Radishes vary in color: some varieties are white, others pink, red, purple, mottled, or black, or red, tipped with white, etc.

RADICULA (Water Cress and Horseradish)

Members of this genus are branching herbs with simple or pinnate lobed, dissected, or rarely, entire *leaves*. *Flowers* are in elongated racemes; they have spreading sepals, yellow or white petals, and one to six stamens. The *siliques* are short or elongated, pencil-shaped, without a stalk or stipe, with one-nerved valves; there are numerous turgid seeds in two rows in each cell, or very rarely one row in each cell.

The genus is one of wide distribution; it is most abundant in the north temperate zone.

There is a rather large number of species, some of which are amphibious, others aquatic. The two principal economic

species are *Radicula armoracia* (horseradish) and *Radicula nasturtium-aquaticum* (water cress). The former is terrestrial, the latter aquatic.

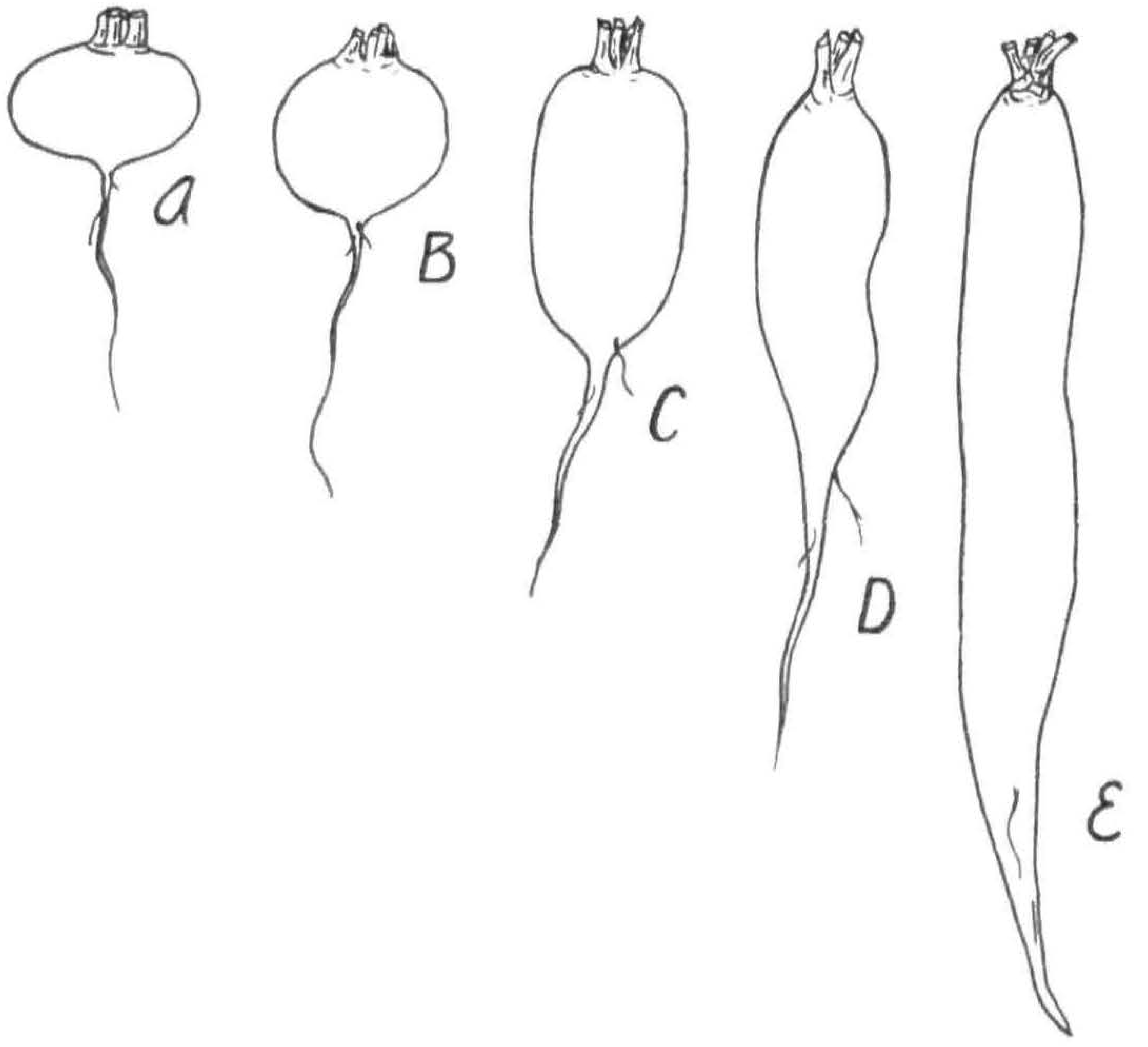


FIG. 147.—Types of radishes (Raphanus sativus). *A*, turnip-shaped; *B*, globular; *C*, olive-shaped; *D*, half-long; *E*, long. (*After Corbett.*)

RADICULA ARMORACIA

(Horseradish) (Fig. 148)

Description.—Horseradish is a hardy perennial from a white, fleshy, cylindrical root which branches at the lower end. The fibrous roots may penetrate to a depth of 6 or 7 feet. In propagating the plant, the slender side roots usually are used; pieces of the main root are also used for this purpose. The plants are 2 to 3 feet tall, branching, with long-petioled, oblong, basal *leaves*, 6 to 12 inches long, that have crenate,

sinuate or pinnatifid margins. The upper leaves are smaller, sessile, oblong, or lanceolate. The *racemes* are terminal or axillary, and bear white flowers. The *pods* are oblong or

FIG. 148.—Horseradish (Radicula armoracia). *A*, basal leaf; *B*, fruit; *C* cauline leaves and inflorescence.

nearly globose and bear a short persistent style. In cultivation, the plant seldom produces seed, but is propagated by root cuttings.

Geographical.—Horseradish is a native of Europe. It is a common home garden plant in the United States, and in some instances has escaped from cultivation and become a troublesome weed.

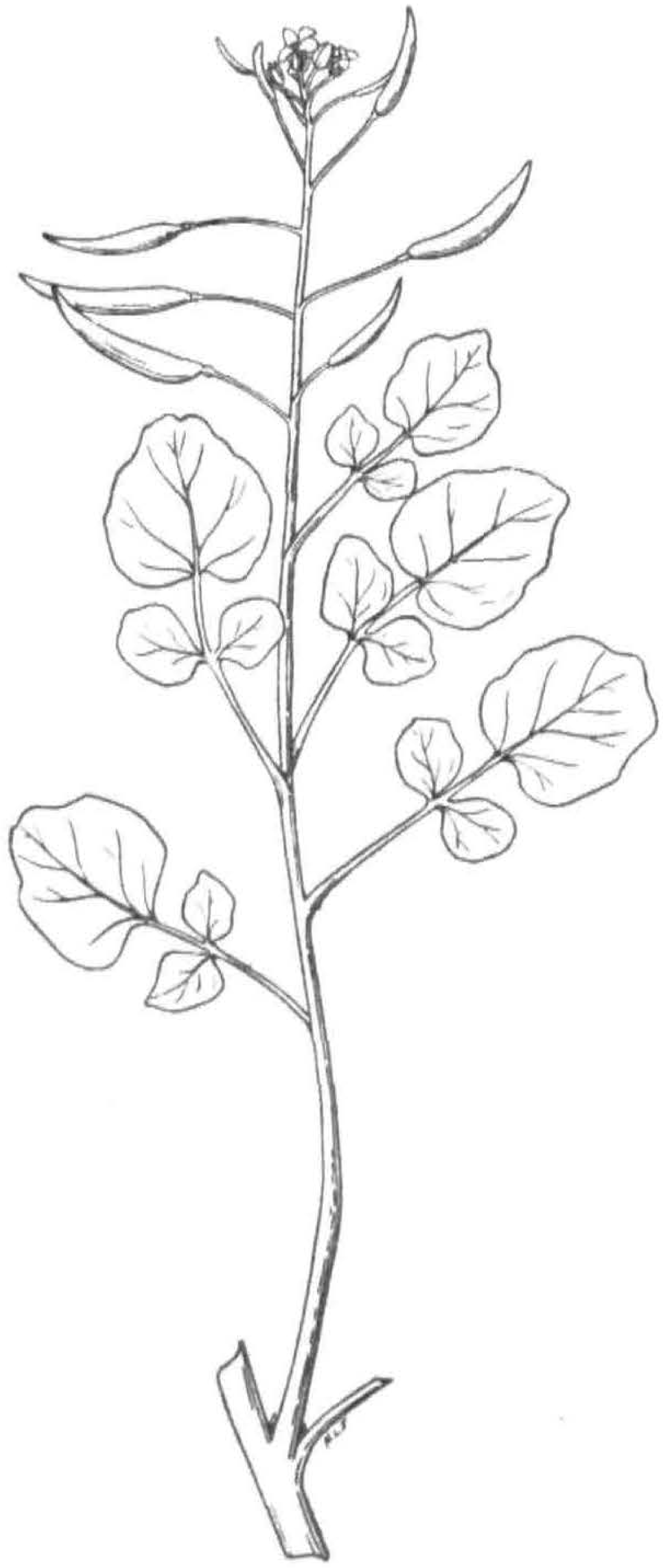


FIG. 149.—Water cress (Radicula nasturtium-aquaticum).

Uses.—The root is grated or scraped, sometimes mixed with vinegar, and used as a condiment.

RADICULA NASTURTIUM-AQUATICUM
(Water Cress)

Description.—This is a perennial, aquatic plant with long floating or creeping stems which readily take root at the nodes. The leaves are compound and odd-pinnate (Fig. 149); the terminal segment is larger than the laterals, all of which are slightly wavy on the margin and of a dark green color. The white flowers are in terminal racemes; the petals are twice as long as the sepals. The siliques (Fig. 149) are slightly curved, on pedicels of equal length, and bear a few seeds in two rows.

Geographical.—Water cress is a native of Europe and Northern Asia, but has become naturalized in both North and South America. It is widespread in North America.

References

Bailey, L. H.: The Cultivated Brassicas. Gentes Herbarium Vol. I, Fasc. II, 53–108, 1922.

Carriere, E. A.: Une nouvelle plante fourragere et economique. Journ. d'Agric. Prat. Annee, 33, tome 11: 845–847, 1869.

Goff, E. S.: Vegetables: Turnip. 6th Ann. Rept. N. Y. Agr. Exp. Sta., 168–190, 1887.

Henslow, G.: The History of the Cabbage Tribe. Jour. Roy. Hort. Soc. (London), 34: 15–23, 1908–1909.

Shaw, T.: The Rape Plant: Its History, Culture, and Uses. U. S. Dept. Agr. Farmers' Bull. 11: 1–20, 1893.

CHAPTER XXVI

ROSACEÆ (Rose Family)

The Rosaceæ are well represented in North Temperate climates. There are about 1,200 species within 65 genera. The most important genera from the crop standpoint are *Rubus* (raspberry, blackberry and dewberry), and *Fragaria* (strawberry). Other genera of importance or of interest are *Spiræa*, an ornamental shrub, *Potentilla* (five-finger or cinquefoil), *Cercocarpus* (mountain mahogany), and *Rosa* (rose).

Leaves.—The leaves are alternate, either simple (as in some *Rubus* species), or compound (strawberry, rose). There are two rather prominent stipules, free from or adherent to the petiole.

Inflorescence.—There are several different kinds of flower clusters in the family. It is a terminal corymb (flat-topped raceme) in *Opulaster*, either racemose, cymose, corymbose or paniculate in *Spiræa*, terminal or axillary and solitary, racemose or paniculate in *Rubus*, and corymbose or racemose in the strawberry. It is interesting to note the great number of different sorts of inflorescences in this one family, and contrast it with the mustard family, in which the raceme is the one prevailing type, or with the carrot family in which the umbel is, with the exception of one genus, the only type, or with the sunflower family, all members of which have a head inflorescence.

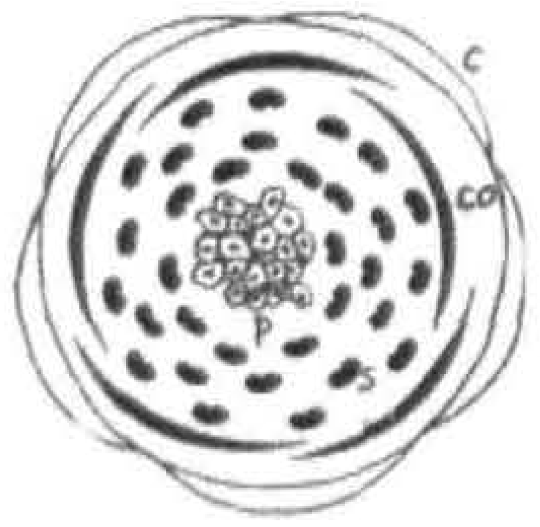


FIG. 150.—Floral diagram of Rubus. (*After Wossidlo.*)

Flowers.—The flowers (Fig. 150) are regular, and usually perfect. In some cultivated strawberries imperfect flowers

are borne. The *calyx* is free from or grown to the ovary, five-lobed, and sometimes subtended by a set of bracts (epicalyx, as in strawberry). The *petals* are distinct, as many as the lobes of the calyx and inserted on the margin of

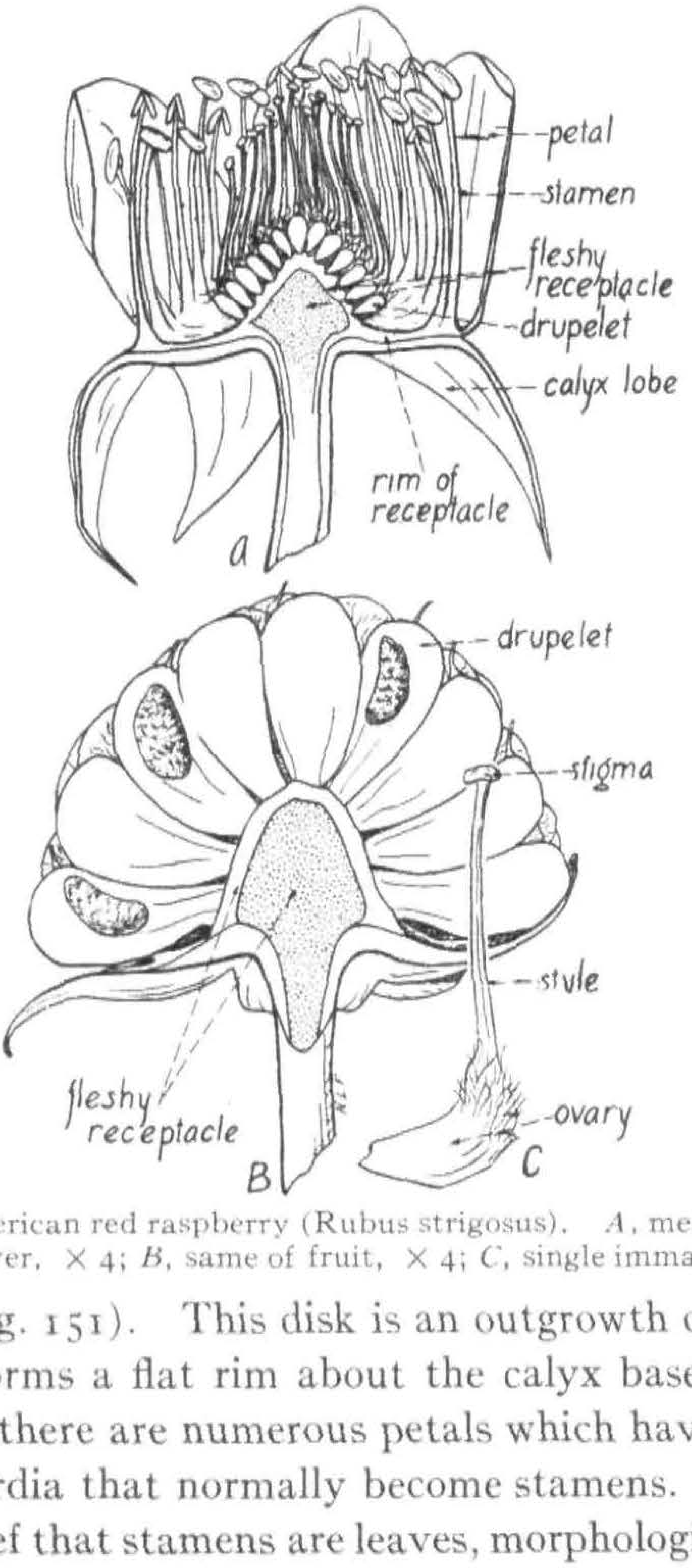


FIG. 151.—American red raspberry (Rubus strigosus). *A*, median lengthwise section of flower, × 4; *B*, same of fruit, × 4; *C*, single immature pistil, × 5.

the disk (Fig. 151). This disk is an outgrowth of the receptacle and forms a flat rim about the calyx base. In cultivated roses there are numerous petals which have developed from primordia that normally become stamens. This bears out the belief that stamens are leaves, morphologically. The production of supernumerary petals is known as "doubling."

The *stamens* are numerous, distinct, and attached to the margin of the toral disk (Fig. 151). The anthers are small and two-celled. The *carpels* are usually numerous and distinct, or rarely attached to the calyx. The ovary is one-celled (rarely imperfectly two-celled) with a terminal or lateral style, and with from one to many ovules.

Fruit.—The fruit is a follicle in *Spiræa*, an aggregate of drupelets in raspberry, blackberry and dewberry, or an aggregate of achenes in strawberry and rose. The follicle is a pod-like fruit, with one carpel, which opens along one side only and usually bears numerous seeds. The true pod, characteristic of the pea family, is a one-carpelled fruit, which splits along two sides. It will be remembered that the capsule has several carpels. A drupelet is a small drupe—a one-seeded fruit with a fleshy mesocarp and stony endocarp.

KEY TO IMPORTANT GENERA OF ROSACEÆ

Fruit not inclosed in a hollow receptacle, *i.e.*, the calyx not constricted over the fruit.
- Carpels becoming follicles, *Spiræa*.
- Carpels become small drupelets crowded on a fleshy receptacle, *Rubus* (raspberry, blackberry, dewberry).
- Carpels becoming dry achenes.
  - Style becoming long and plumose, *Cerocarpus* (mountain mahogany).
  - Style short.
    - Receptacle fleshy in fruit, *Fragaria* (strawberry).
    - Receptacle not fleshy in fruit, *Potentilla* (five-finger or cinque-foil).

Fruit inclosed in a hollow receptacle, *i.e.*, the calyx constricted over the fruit, *Rosa* (rose).

RUBUS (Raspberry, Blackberry, Dewberry)

Stems.—The plants of this genus are usually shrubs, rarely herbs (*Rubus Chamæmorus*, cloudberry, knotberry or mountain bramble). They are usually designated as "brambles." The stems are, as a rule, prickly, erect, decum-

bent, or creeping. The stems ("canes") commonly die after one or two years, new ones being sent up from the roots. The main growth of the stem is made during the first year, in

FIG. 152.—Fruiting branch of American red raspberry (Rubus strigosus).

most Rubi; side branches are produced the second year; the flowers and fruit are developed on these side branches. The entire cane usually becomes weak and dies after fruiting. This suggests the advisability of removing canes once they have borne fruit.

Propagation.—Red raspberries, blackberries and dewberries (rarely) "sucker" readily. This natural tendency to send up sprouts from the roots is taken advantage of by the fruit-raiser. All plants which reproduce naturally from suckers are easily propagated from root cuttings. Black-

cap raspberries and dewberries produce stolons. A shoot bends over by its own weight and takes root at the tip. When once the tip has rooted well, the shoot may be cut loose from the parent stem and such rooted tips used as "sets."

Leaves.—These are alternate, simple, palmately lobed or compound three- to seven-foliate, and bear persistent stipules. In *Rubus trivialis*, southern dewberry, the leaves are evergreen.

Inflorescence.—The flowers are terminal or axillary, solitary, in panicles or racemes. The flowers and fruit in all representatives of the genus *Rubus* are borne on shoots which arise from the growth of the year before. For example, in 1913, a shoot (cane) is sent up from the root and in the axils of the leaves are buds. In 1914, these lateral buds develop into leafy shoots with terminal inflorescences and single flowers or flower groups in the axils of leaves. The shoots, developed in 1913, once having borne fruit in 1914, are no longer useful. The cutting out of these useless shoots will induce the development of new ones from the roots.

Flowers.—The flowers (Fig. 151, A) are rather large, regular, and usually perfect. In *Rubus vitifolius*, the Pacific Coast dewberry, however, there are both hermaphroditic and pistillate plants. *Rubus Chamæmorus* is diœcious. The receptacle is flat or convex. The five-parted calyx is persistent in the fruit. There are five petals, which are usually white, and deciduous. The stamens are numerous, and attached at the base of the disk. The numerous pistils are separate and crowded on the receptacle; each pistil bears a single thread-like style. The styles are hairy and somewhat broadened at the base in the raspberry; while they are narrow and free from hair at the base in the blackberry.

Pollination.—As a rule, the anthers and stigmas mature simultaneously. There is abundant nectar secreted by a fleshy ring on the margin of the receptacle, inside of the

stamens. Insects facilitate pollination. Better yields are secured, in the case of some dewberries, if they are planted adjacent to another variety so that cross-fertilization will result.

Fruit.—The fruit (Fig. 151) of the genus is an aggregate. The numerous pistils ripen into drupelets which cling together to a greater or less degree. In the dewberries and blackberries, the drupelets are firmly attached to the receptacle while in raspberries the drupelets readily separate from the receptacle when the fruit is being picked, clinging together in the form of a cup. The exposed surface and the angles between the faces of each drupelet are pubescent in the raspberry, and the faces themselves are glabrous. The sticking together of the drupelets is due to the interlocking of these crooked hairs. The blackberry and dewberry drupelets are glabrous throughout.

Geographical.—The Rubi are of wide geographic distribution; the greater number of species, however, occurs in North Temperate regions.

Classification.—The numerous members of the genus fall into three groups which may be distinguished as follows:

Key to Groups of Genus Rubus

Drupelets firmly attached to receptacle, not separating from the latter when fruit is being picked.
  Stems upright; plant propagating by suckers; lower, outer flowers open first, *Blackberries*.
  Stems trailing; plant propagating by tips; center flowers open first, *Dewberries*.
Drupelets readily separating from the receptacle when fruit is being picked, clinging together in form of cup, *Raspberries*.

BLACKBERRIES

Only those species are considered in the following keys which have yielded us our important fruit-bearing varieties. The key considers the groups of blackberries as given by L. H. Bailey in "The Evolution of Our Native Fruits."

KEY TO SPECIES OF BLACKBERRIES

Inflorescences conspicuously loose, the few flowers scattered on long pedicels, *Rubus nigrobaccus* × *R. villosus* (loose-cluster blackberries or blackberry-dewberry).

Inflorescences more compact, the flowers not so scattered along the main axis.

  Inflorescences leafy, *i.e.*, pedicels subtended by leaves, *Rubus argutus* (leafy-cluster blackberries).

  Inflorescences entirely or almost leafless.

    Clusters long.

      Berries black, *R. nigrobaccus* (common long-cluster or high-bush blackberry).

      Berries cream-colored or pink, *R. nigrobaccus* var. *albinus* (white blackberry).

    Clusters short.

      Lower surfaces of leaves white-pubescent; plants 1 to 3 feet tall, very thorny, *R. cuneifolius* (sand blackberry).

      Lower surfaces of leaves pubescent but not whitish; plants 1 to 8 feet tall, thorny, *R. nigrobaccus* var. *sativus* (short-cluster blackberries).

Rubus nigrobaccus.—The tall stems are furnished with strong, hooked prickles. The long-stalked leaves have ovate and distinctly pointed leaflets. Inflorescences are long, glandular-hairy racemes with large, showy flowers on pedicles that stand out almost at right angles. The fruit is firm, oblong, sweet, and aromatic.

The plant is found throughout eastern United States and northward into Canada. The variety Taylor is the best known. Snyder and Kittatinny are common varieties of the short-cluster blackberries. The white blackberry has greenish-yellow stems and cream-white fruits, and occasionally grows wild.

Rubus nigrobaccus × R. villosus.—The loose-cluster blackberries are considered to be hybrids between the high-bush or long-cluster blackberry and the northern dewberry. The plants are rather low and spreading and have characteristic, broad, jagged leaflets.

The fruits are small and globular or globular-oblong, and grow in small clusters. Wilson and Rathbun are typical varieties.

Rubus argutus.—The plants are erect, stiff, prickly, and with stems strongly angled, almost grooved. The small leaflets are firm and rather rigid, and coarsely toothed. Inflorescences are short and leafy. The fruit is small, globular, and black. The species is found growing wild from New England to Florida and Arkansas. Common varieties are Dorchester, Early Harvest, and Brunton Early.

Rubus cuneifolius.—The sand blackberry is a stiff, thorny plant about 3 feet tall. The leaflets are thick, obovate, and white-pubescent beneath.

Inflorescences are short and bear but a few (two to eight) flowers. The fruit is of medium size, sweet, and desirable. This species grows wild from southern New York and Pennsylvania to Florida, Louisiana and Missouri. Topsy is the common cultivated variety; it often does not have the pubescence of the species.

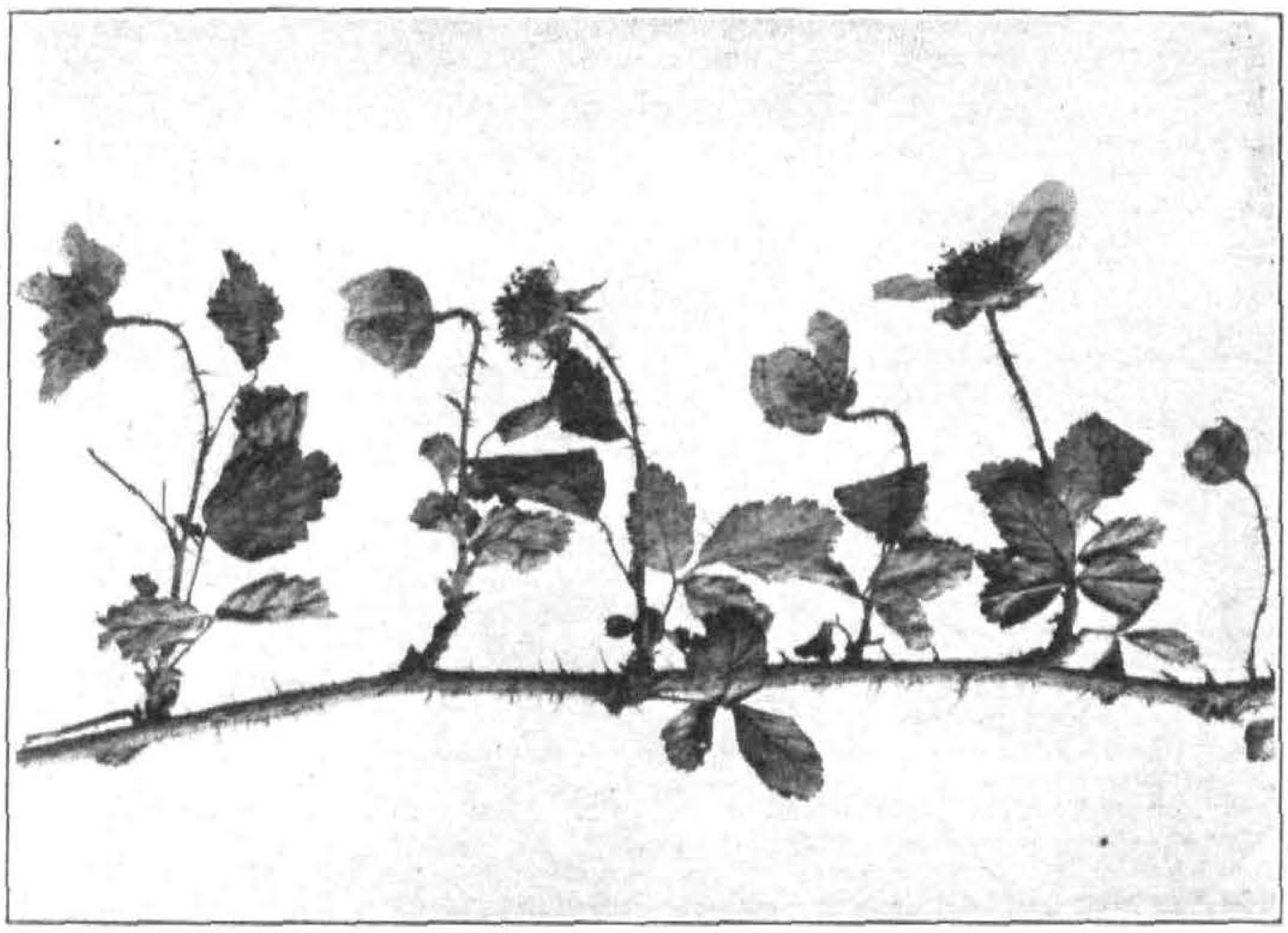


FIG. 153.—Northern dewberry (Rubus villosus).

DEWBERRIES

These differ from blackberries in their trailing habit, cymose inflorescences, and propagation by tips. They have received the name "trailing blackberry." There are four principal groups of dewberries, which are distinguished in the following key:

KEY TO PRINCIPAL SPECIES OF DEWBERRIES

Leaves evergreen, *R. trivialis* (southern dewberry).
Leaves deciduous.
  Buds tipped by the united ends of the sepals, forming a spine; flower clusters forking into two or three parts, *R. invisus* (northern dewberry).
  Buds not tipped by the united ends of the sepals to form a spine.

Both hermaphrodite and pistillate plants; leaflets coarsely toothed, *R. vitifolius* (western dewberry).

Plants all perfect; leaflets finely toothed, *R. villosus* (northern dewberry).

Rubus trivialis.—These are trailing shrubs, with stout, hooked prickles and bristles on the stems, and with upright branches 3 to 9 inches tall. The leaves are trifoliate, petioled, and with oval, leathery, serrate, evergreen leaflets. The inflorescences are one- to five-flowered. The flowers are large, white, and have petals that are much longer than the sepals. The fruit is black, and up to 1 inch long. The species occurs from Virginia to Florida and westward to Texas and Missouri. The best-known horticultural variety is Manatee.

Rubus invisus.—The stems are moderately prickly. The leaflets are large and coarsely and simply dentate. The erect peduncles are elongated. The large flowers are on long pedicels; flower buds are tipped by the united ends of the sepals. The species is reported by Bailey as growing wild from New York to Alabama and east to Kansas and Missouri. The chief varieties are Bartel and Mammoth.

Rubus vitifolius.—This species occurs in California, Oregon, Washington and Idaho. Skagit Chief is the principal form in cultivation.

Rubus villosus.—The plants are robust, with smooth stems and large, thick leaves, which have three to seven oval or ovate, long-pointed and sharply double-toothed leaflets. The inflorescences are one to three-flowered, leafy, and cymose. The fruit is globular, and has a few, shining-black, and sweet drupelets. This is the common dewberry of the Northern States; it is found growing wild from Newfoundland to Virginia and westward to Minnesota and Kansas. Windom, Geer and Lucretia's Sister are varieties. The Lucretia dewberry (*variety roribaccus*) is a more robust form with large wedge-obovate, jagged leaflets, and large flowers on long pedicels.

RASPBERRIES

There are four well-known groups of cultivated raspberries: black-cap, purple-cane, American red, and European red.

Key to Principal Species of Raspberries

Fruit purple-black, rarely yellow; propagating by tips, *R. occidentalis* (black-cap).

Fruit purple, dark red, light red, or sometimes yellow; propagating by tips or suckers.

Stems stiff and erect; fruit produced more or less continuously throughout the season, *R. idæus* (European red).

Stems more slender and drooping; fruit produced less continuously throughout the season.

Stems bristly, not glaucous; fruit light red; inflorescence racemose, *R. strigosus* (American red).

Stems prickly, slightly glaucous; fruit dark red; inflorescence racemose-cymose, *R. strigosus* × *R. occidentalis* (purple-cane).

Rubus occidentalis.—The slender stems are often 10 to 12 feet long, rooting at the tip, sparingly supplied with small hooked prickles, and sometimes glandular-bristly above. The leaves are trifoliate, stipulate, with oval or acuminate, toothed leaflets, that are white-hairy on the under side. The inflorescences are dense, and corymbose. The flowers are on short pedicels; the petals are shorter than the sepals. The black-cap raspberries are the most important in this country. The species is found throughout eastern United States, northward into Quebec and Ontario, and westward to Oregon and British Columbia.

Some of the western forms have been given distinct specific names (*R. leucodermis*, *R. glaucifolius*, *R. bernardinus*.

Rubus idæus.—The stems are stiff and erect, and furnished with prickles; glandular bristles are never present except in some cultivated forms which may be considered as hybrids between *R. idæus* and *R. strigosus;* pubescence occurs on peduncles, pedicels, petioles are nearly always flattened and slightly curved. The thick leaves are white-downy beneath. The fruit is purple or yellow and is produced throughout the season. The European raspberry is not cultivated to any extent in this country at the present time. It is a native of Europe and Asia.

Rubus strigosus.—The stems are slender and bear stiff, straight or hooked prickles; glandular bristles occur on peduncles, pedicels, petioles, and calyx. The leaves are three- to five-foliate, with ovate or oblong-ovate, sharply serrate or lobed leaflets, which are whitish-pubescent beneath. The inflorescences are terminal or axillary, and racemose; the flowers are white. The fruit is light red, rarely yellow, and is not produced continuously throughout the season. *Rubus strigosus* is the native, common red raspberry. It is distributed from North Carolina to New Mexico, northward in the Rocky Mountains to Manitoba and British Columbia and eastward to Newfoundland and Labrador. Cuthbert is one of the principal varieties.

Rubus strigosus × R. occidentalis (R. neglectus).—The stems are long and often rooting at the tip, glaucous, prickly, and bristly. The inflorescence is racemose-cymose and has short, erect or ascending peduncles. The fruit varies in color from purple-black to bright purple, and sometimes yellow. Shaffer and Columbian are the chief varieties.

The Loganberry.—This is an important fruit that has resulted from crossing a blackberry and a raspberry. It is supposed that the blackberry was the variety Aughinbaugh and the raspberry, Red Antwerp. Aughinbaugh is a pistillate variety of *R. vitifolius*. Evidence[1] has recently been presented tending to show that the loganberry has behaved as a true species,

[1]Journal of Heredity, 7: 504–507, 1916.

and is not a hybrid. The loganberries are large, often 1 to 1¼ inches long, and of a rich, dark red color, but unfortunately not of very superior flavor.

Mayberry.—This is supposed to be a cross between a Japanese species, *Rubus microphyllus* and Cuthbert, a variety of *Rubus strigosus*.

FRAGARIA (Strawberry)

Roots and Stems.—Strawberries are low, perennial plants with very short, thick stems set close to the surface of the

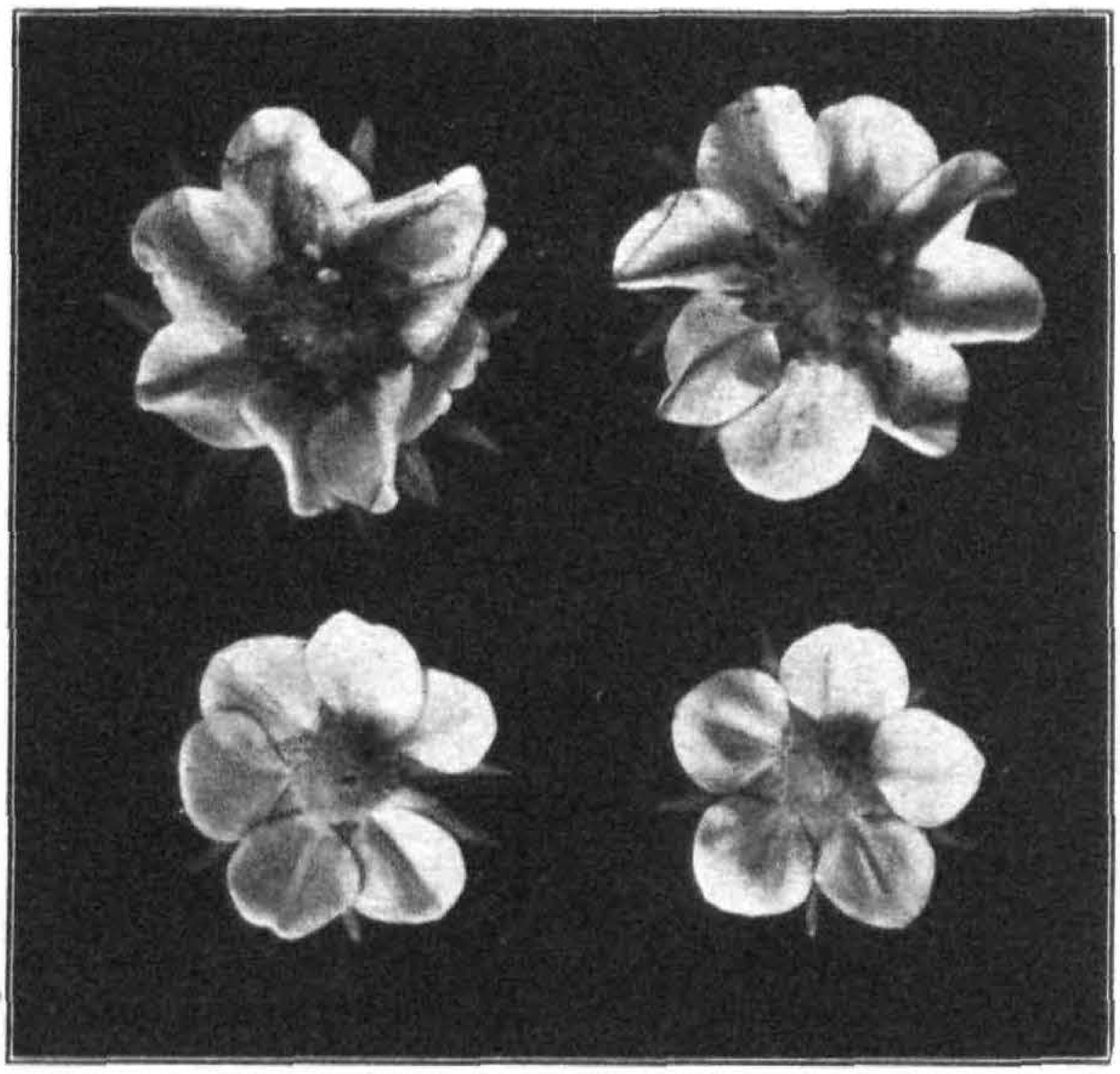


FIG. 154.—Flowers of strawberry (Fragaria chiloensis). Above, two perfect flowers; below two pistillate flowers.

ground. Such very short-stemmed plants are usually termed "acaulescent." The branches that arise from the axils of the closely set leaves are called "*runners*." Runners are slender stems, growing along the ground surface; they have long internodes, and produce leaves and flowers and roots at the nodes. Runners are used as a means of propagating the plant. They are attached to the old plant for

but one reason. In the Virginian group of strawberries, the runners start to form as early as new leaves are produced and may attain a considerable length before the fruit is mature. In the Chilean group, the runners are usually formed after the fruit is matured. Runners may branch. New branches from the main perennial stem appear, of course, above the

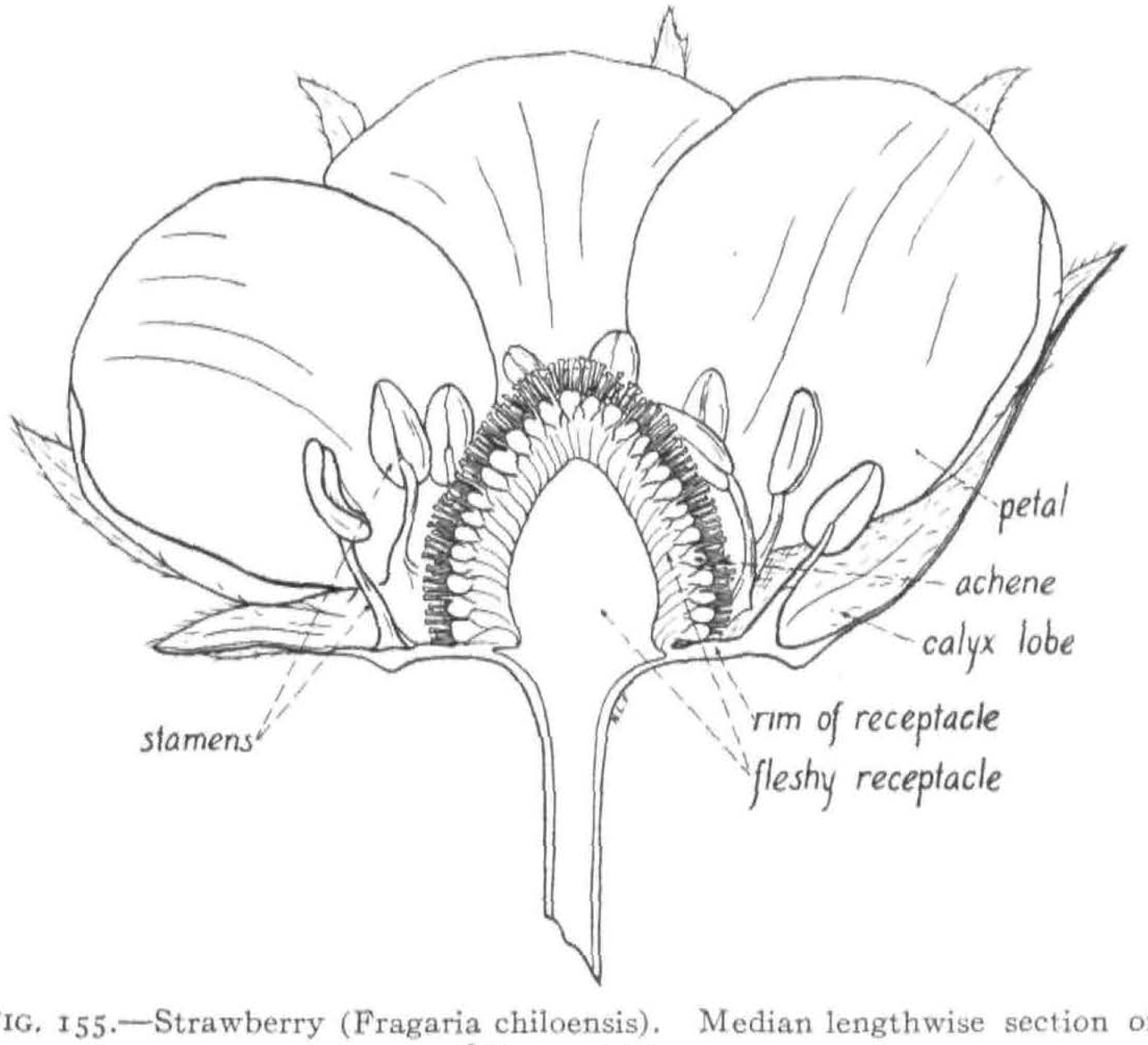


FIG. 155.—Strawberry (Fragaria chiloensis). Median lengthwise section of flower. × 4.

old ones, hence there is a tendency for the short stem to become more and more exposed above the ground surface. Roots do not extend over a depth of 2 feet in the soil, and horizontally, scarcely beyond the area covered by the leaves. Practically all roots are within the first foot of soil.

Leaves.—The leaves are alternate and arise in a tuft; the petioles are usually much longer than the leaf blades, which

are divided into three leaflets (trifoliate); sheathing, membranous, adnate stipules which increase in size as the leaf grows, occur at the base of the petiole.

Inflorescence and Flowers.—The white flowers are in small racemes or corymbs on long, erect, leafless scapes which spring from the crown of the plant. The flowers are usually perfect; however, there are some varieties (Bisel, Princess, Warfield, etc.) which have only pistillate flowers (Fig. 154); there are no commercial varieties that have only staminate flowers. In planting varieties with pistillate flowers only, it is necessary to have rows near-by planted to pollen-bearing individuals. Some perfect-flowered varieties (Glen Mary and Crescent) bear very few stamens, and hence are practically self-sterile. The receptacle is convex or conical (Fig. 155). The calyx is five-parted, with five-bracteoles (epicalyx) below, that are persistent in the fruit. There are five obovate, short-clawed petals, attached to the rim of the receptacle. There are numerous stamens, as a rule, sometimes a few or none; they are attached to the rim of the receptacle, persistent in the fruit, and possess slender filaments and small anthers. Pistils are numerous on the smooth, convex, or conical receptacle which becomes modified in the fruit (Fig. 156, A). Each carpel bears a style laterally placed (Fig. 156, B), and a single ovule.

Fertilization, and Development of the Fruit.—Strawberries are protogynous, that is, the pistils of a flower mature before its stamens. Hence cross-fertilization is secured; and this usually by insects. Non-fertilization or incomplete fertilization is usually indicated by berries with hard, greenish, undeveloped apices, so-called "nubbins." The true fruits of a strawberry are the achenes (so-called "seeds") scattered over the fleshy receptacle. Unless the ovules are fertilized, the receptacle does not mature properly. This behavior is the rule in most plants. When a sperm nucleus of the pollen

tube unites with the egg nucleus of the ovule, resulting in fertilization, there is set into action a train of changes which not only involve the ovule itself, but which extend to the ovary wall, and, as in the strawberry, to the receptacle.

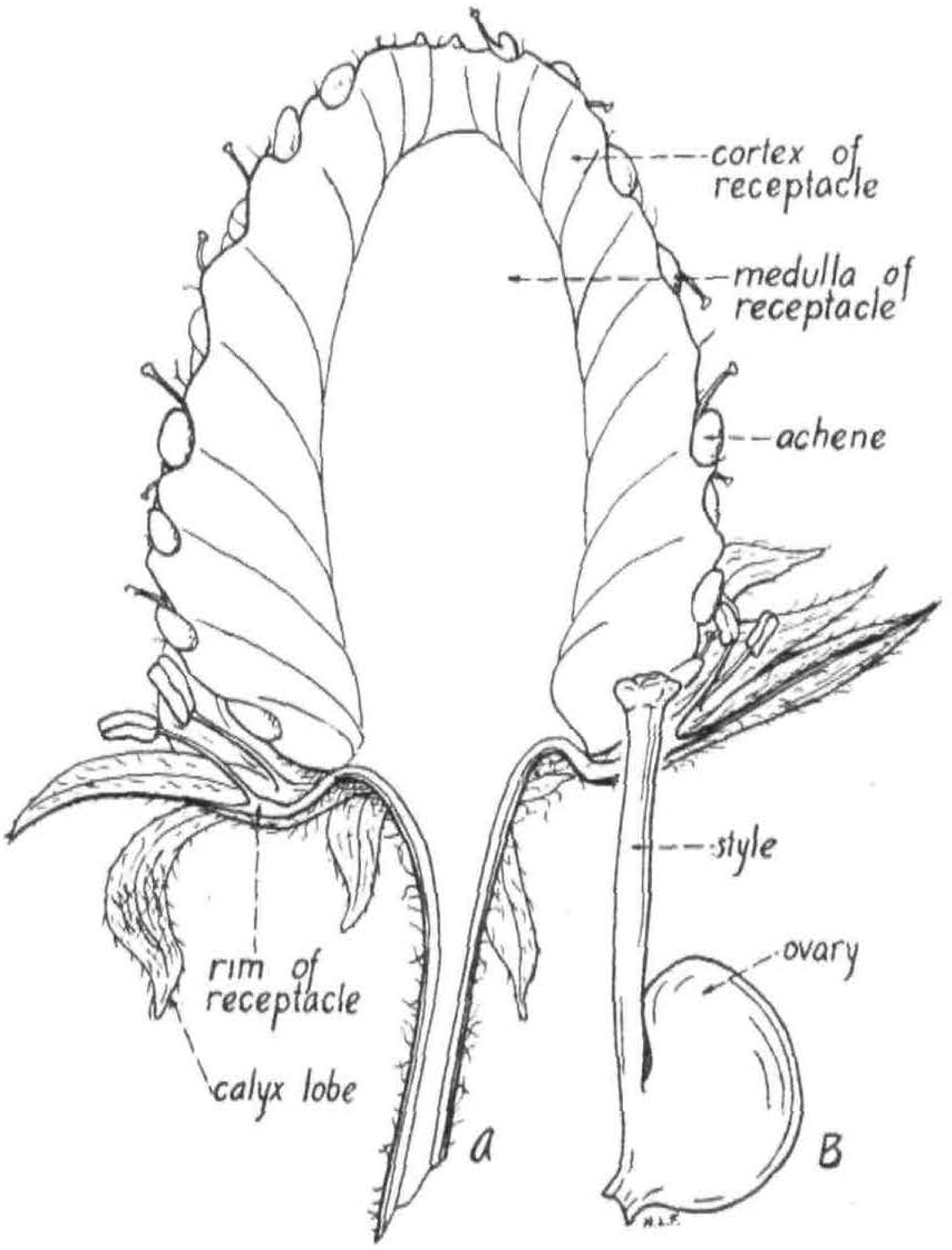


FIG. 156.—Strawberry (Fragaria chiloensis). A, "fruit" in median lengthwise section, × 2½; B, single achene, × 20.

The Mature Fruit.—The strawberry "fruit" (popularly speaking) is an aggregate of true fruits. The fleshy part of the "fruit" is receptacle, while the true fruits (botanically speaking) are achenes partially imbedded in the surface of the receptacle. In a lengthwise section (Fig. 156, A) of the ripened fruit, the receptacle is seen to be composed of a

fleshy pith and cortex with fibro-vascular bundles between them. It is in reality stem structure. These bundles send off side branches into the cortex, and some of them extend to the achenes. The persistent calyx and epicalyx, and withered stamens are at the base of the fruit. These constitute the "*hull*" of the fruit. The achenes are attached to the receptacle a short distance above their base and the styles arise from the ventral side, a little above the point of attachment of fruit to receptacle. The achenes are commonly termed "seeds."

Geographical.—The genus *Fragaria* possesses about eighteen species most of which are natives of the north temperate zone; a number are found in the Andes of South America. Strawberries are cultivated in all parts of the United States.

Principal Fruit-bearing Species.—The evolution of the strawberry has been given to us by Bailey. Most of our cultivated varieties of strawberries belong to the species *Fragaria chiloensis*. This plant is a native of western Chile, from which country it was brought to Europe at the beginning of the eighteenth century. The Chilean strawberry is also a native of the western coast region of North America, as well as of South America. However, some botanists would refer the forms as found in this continent to the species *Fragaria californica* and *F. glauca*.

The early settlers in the Eastern States cultivated the common wild strawberry (*Fragaria virginiana*) which they found growing in their fields. But few cultivated varieties belong to it. Varieties of the wild strawberry of Europe (*Fragaria vesca*) have also been cultivated in America, but only to a slight extent. These varieties are the Everbearing or Perpetual strawberries.

Hence, the varieties of strawberries in America fall into three groups, as follows:

1. Chilean group from *Fragaria chiloensis*.
2. Scarlet or Virginian group from *Fragaria virginiana*.
3. Perpetual or European group from *Fragaria vesca*.

These three species may be distinguished by the following key:

Key to Principal Species of Fragaria

Leaves usually projecting above the flowers and fruit; achenes sunken in the flesh.
  Runners appearing after the fruit; berry dark; calyx large; leaves shining above, bluish-white beneath, *F. chiloensis* (Chilean strawberry).
  Runners appearing with the fruit; berry scarlet; calyx medium; leaves light green on both surfaces, *F. virginiana* (scarlet or Virginian strawberry).
Leaves usually not projecting above the flowers and fruit; achenes not sunken in the flesh, *F. vesca* (perpetual or European strawberry).

Fragaria virginiana (*Virginia or Scarlet Strawberry*).—This is a stout, dark green, tufted herb with soft-hairy leaves. The petioles are from 2 to 6 inches long, the leaflets oval or obovate, obtuse, dentate, the lateral not symmetrical at the base. The scape is usually shorter than the leaves, at least not exceeding them, hence the fruits are borne below the leaves. The calyx lobes are erect at maturity. The fruit is red, ovoid, and with achenes imbedded in the flesh.

The species extends from New Brunswick to South Dakota, south to Florida, Louisiana and Arizona.

Fragaria vesca (*European Wood or Everlasting Strawberry*).—This is a stout, dark green, tufted plant with hairy leaves. The leaflets are ovate or broadly oval, obtuse, dentate, the lateral not symmetrical at the base. The scape is longer than the leaves, hence the fruits are borne above the leaves. The calyx lobes are spreading or reflexed. The fruit is red, hemispheric or conic, with achenes not imbedded in the flesh.

This strawberry is a native of Europe, but naturalized in the Eastern and Middle States. It has given us our Perpetual and Ever bearing varieties.

Fragaria chiloensis (*Chilean Strawberry*).—The Chilean strawberry is a low form with thick leaves, shining above and bluish-white beneath; the runners appear after the fruit is gone. The fruit is large, firm, dark, with a large "hull," and with achenes sunken in the flesh.

It is a native of the western coasts of South America and North America. Most of the common varieties of strawberries belong to the Chilean species.

Varieties.—The number of varieties of strawberries is great. They are commonly divided into three groups as to

time of maturing: first; *early* (Warfield, Excelsior, Bederwood); second, *medium* (Ridgeway, Dunlap, Marshall, Jucunda); and third, *late* (Aroma, Gandy, Chesapeake, Splendid). Growers distinguish between commercial varieties and those for home consumption. A good commercial variety should be hardy, very productive, of good color, firm, and of good size and form. Among good commercial varieties, may be mentioned Bederwood, Excelsior, Jucunda, Dunlap, Captian Jack, Splendid, and Parson's Beauty. Such varieties as Warfield, Ridgeway, Marshall, Aroma, and Chesapeake are grown for home use.

Origin of New Varieties.—Strawberries seldom come true to seed; hence it is possible to secure new varieties by planting seed. When a desirable variation appears, it is propagated and kept "true" by means of runners. This method of vegetative propagation insures permanency in the characters of the variety selected.

Uses.—Strawberries are used chiefly in the fresh state. There is an increasing demand for such strawberry products as crushed fruit, preserves, marmalades, and jellies. Large quantities are put up fresh for use at soda fountains and in the manufacture of ice cream.

References

Bailey, L. H.: Survival of the Unlike. Essay 25, Strawberries, The MacMillan Co., 1896.

Blanchard, W. H.: Rubus of Eastern N. A. Bull. Torrey Bot. Club, 38; 425–439, 1911.

Bunyard, E. A.: The History and Development of the Strawberry. Jour. Hort. Soc., 39: 541–552, 1914.

Corbett, L. C.: Strawberries. U. S. Dept. Agr. Farmers' Bull. 198: 1–24, 1904.

CHAPTER XXVII

POMACEÆ (Apple Family)

Members of the apple family are either trees or shrubs. The alternate simple or compound leaves are petioled, and have small deciduous stipules.

Inflorescence.—The inflorescences are racemose (*Amelanchier*, service-berry), cymose (*Malus*, apple, *Sorbus*, mountain ash) or simple (*Cotoneaster*, evergreen or fire thorn).

Flowers.—The flowers (Fig. 161) are regular, perfect, and usually with a concave or cup-shaped receptacle or torus to which is attached a five-lobed or five-toothed calyx, five separate petals, numerous distinct stamens and a one- to five-celled ovary. The *ovary* is ordinarily five-celled, and the carpels are wholly or partly united. The *carpels* vary in texture from parchment-like (*Malus*, etc.) to bony (*Cratægus* and *Cotoneaster*). The number of *styles* varies in the different genera: generally three in *Sorbus*, two to five in *Malus* (usually five), mostly five in *Pyrus* (pear), two to five in *Amelanchier*, one to five in *Cratægus* (thorn apples), two to five in *Cotoneaster*. They may be distinct, as in *Sorbus*, or partly united as in *Malus*. The ovules are commonly two (*Malus*) in each cell, sometimes one (*Amelanchier*), or rarely several (*Cydonia*, quince).

Fruit.—The *fruit* is a pome. Representatives of the family are commonly spoken of as "pomaceous." The pome is a false or spurious fruit in which the receptacle or torus becomes fleshy, to form the greater portion of the fruit, and encloses five bony, leathery or papery carpels (Fig. 162).

Geographical.—The family is of wide geographical distribution, there being close to 225 species within about 20 genera. Most of the species occur in north temperate or boreal regions.

KEY TO IMPORTANT GENERA OF POMACEÆ

Ripe carpels bony, *Cratægus* (thorn-apple, haw, hawthorn).
Ripe carpels papery or leathery.
  Leaves compound, *Sorbus* (mountain ash).
  Leaves simple.
    Ovules one in each cavity, *Amelanchier* (service-berry, June-berry).
    Ovules (usually) two in each cavity.
      Flesh of the pome with grit-cells, *Pyrus* (pear).
      Flesh of the pome without grit-cells, *Malus* (apples and crab-apples).
    Ovules many in each carpel, *Cydonia* (quince).

MALUS (Apples)

Stems.—Malus species are either trees or shrubs. In the apple, all rapid-growing shoots develop only leaf buds. Flower buds, which in the apple are "mixed" buds, are almost always borne on the ends of "*spurs*" or short twigs. When a "spur" terminates in a flower bud, lateral buds lower down continue the growth of the shoot, hence the crooked appearance of such spurs (Fig. 157). These lateral buds may grow for a year or so, bearing leaf buds at the terminus, and then be stopped in their growth in that direction by the formation of a terminal flower bud. As a rule, a shoot that has once started to bear flowers continues to do so, making but a very short growth of wood each year. Such a shoot is marked by the closely crowded leaf scars, terminal-bud scars, and flower and fruit scars. The position of a fruit is usually marked by a large circular scar surrounded by a number of smaller ones of the same shape. The smaller ones represent scars made by flowers or fruit that failed to develop. It has been recorded generally, particularly for Eastern orchards, that the fruit buds in apples are always terminal, and furthermore that the fruit spur must be two or more years old before it will bear fruit. Paddock and Whipple ("Fruit Growing in

Arid Regions") have noted that in certain districts of Colorado many varieties produce flower buds in the axils of leaves

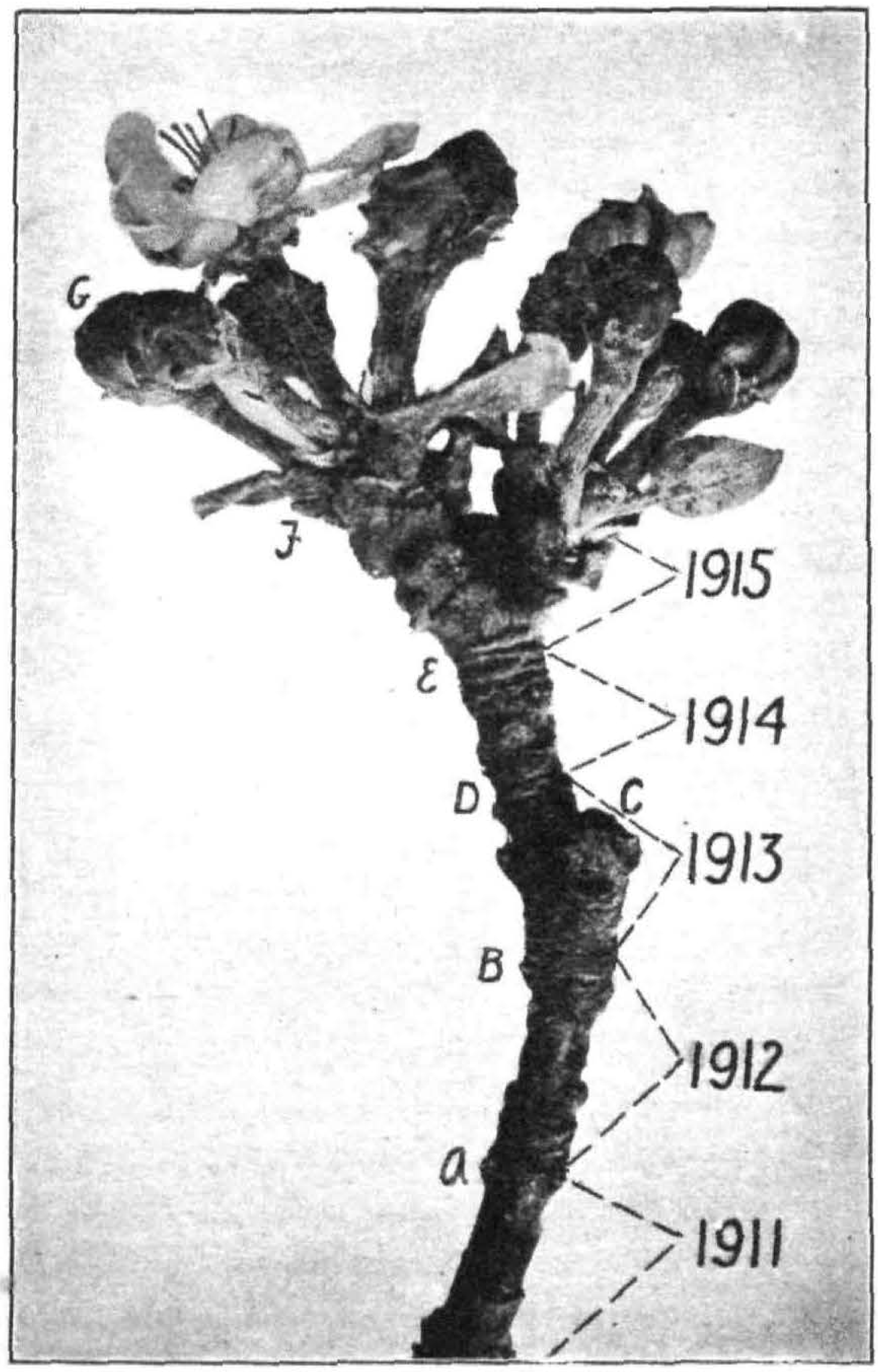


FIG. 157.—Spur of Yellow Transparent apple.

on the growth of the current season and that one-year-old spurs may in many instances bear fruit, or that fruit may be borne at the end of last year's terminal growths, not spurs. Hyslop, Mann, Missouri Pippin, Strawberry,

Striped, Transcendent and Winesap are among those varieties producing fruit in the axils of leaves. Astrachan, Ben Davis, Grimes, Hyslop, Jonathan, McIntosh, Missouri Pippin, Newton, Northern Spy are a few varieties found to be bearing fruit on one-year-old spurs. A few varieties such as Grimes, Hyslop, Transcendent, Willow Twig, and Yellow Transparent produce fruit on the end of last year's terminal growths, not spurs.

FIG. 158.—Mature Jonathan apples from axillary flower buds. (*After Paddock and Whipple.*)

Gourley has observed axillary fruit buds throughout the Eastern States on both old and young trees, and in many varieties. Different forms of fruit branches occur; furthermore the same variety, or even tree, may bear more than one sort of fruit branch. Frequently, it has been noted that spurs bear annually, instead of biennially, as is the rule. In such a case, fruit buds are developing on a spur at the same time that an apple is maturing.

It is not always an easy matter to distinguish between the fruit and leaf buds of apple. Generally, fruit buds are rather thick and rounded, while leaf buds are smaller and more pointed.

It has been shown that fruit buds are differentiated very early, and may be distinguished by microscopic study, from leaf buds, as early as the last week in June of the year preceding the opening of the flower. The above has been reported by Drinkard, and Kraus has observed that in the Yellow Newton apple, under Oregon conditions, the fruit and leaf buds are differentiated in early July, and in early varieties, even by the latter part of May.

The form of the tree, nature of twigs, branches, bark and leaves vary a great deal in the many varieties of apples.

Leaves.—These are simple, alternate, and toothed or lobed; the stipules are free from the petiole. Some use is made of leaf characters in the identification of common apple varieties.

Inflorescence.—It will be recalled that the buds containing flowers are mixed buds. Hence, when each opens there is developed a very short axis bearing closely crowded leaves and flowers. On this axis, the flowers are apical, the leaves basal. The flowers may be so crowded that the cyme is umbel-like in appearance. In most cases, the inflorescence is terminal, but, as has been indicated above, it is axillary in some varieties. The number of flowers in a single mixed bud may vary from two or three to eight or ten. As a rule, but one flower matures its fruit, thus illustrating the struggle for existence among the different individual flowers.

The determinate inflorescence, cyme, of apple is not always definitely so. It will be remembered that in the cyme type of inflorescence the flowers open in order from the inside outward. Sometimes the central flower is tardy in its development, and often the central and some of the laterals may open simultaneously.

Flowers and Their Development.—The development of the apple flower (Yellow Newton) has been worked out by Kraus. A longitudinal section (Fig. 159) of a growing axis shows a number of bracts and bud scales surrounding it; on the sides of the axis, appear the primordia of flower buds and leaves. The primordia of sepals are the first to appear. The torus develops especially toward the outer edge by a growth of the cells beneath the developing calyx, and finally takes on a concave shape. The torus continues to uprise during the development of petals and stamens, both of which are seen to arise from the concave sides of the torus. Following the appearance of sepal primordia, appear petal primordia, then those of stamens, and lastly those of the carpels.

The succession of floral cycles is acropetal, *i.e.*, in order from without to the inside.

The primordia of stamens appear in three cycles, those of the outer usually being laid down first (Fig. 160). The carpel primordia appear within the central portion of the cup-shaped torus. There are five of these surrounding a small central cavity, which is formed by a lack of growth at the center of the torus. Hence there is no common placenta, but each carpel has its two separate placentas, which in

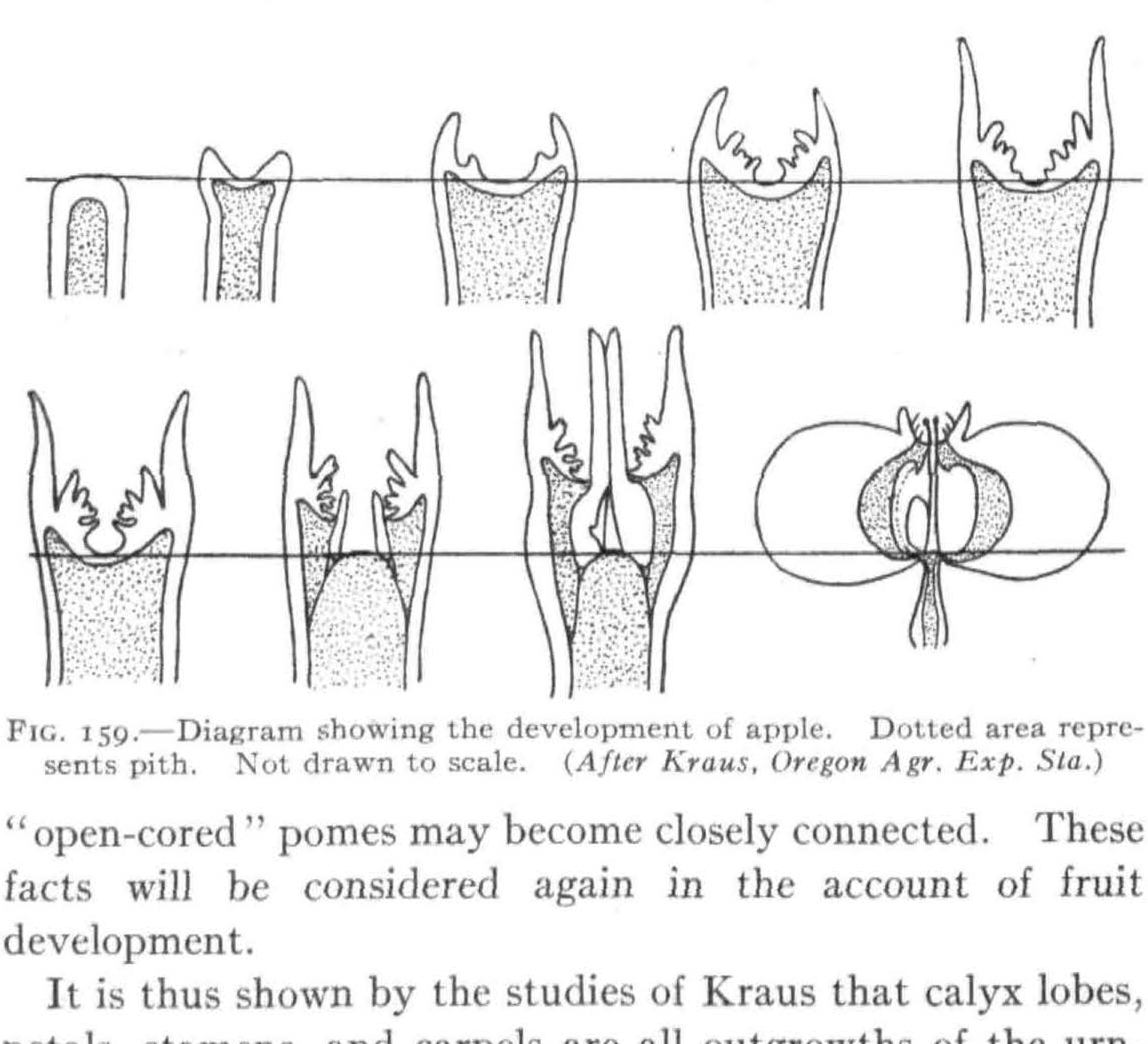


FIG. 159.—Diagram showing the development of apple. Dotted area represents pith. Not drawn to scale. (*After Kraus, Oregon Agr. Exp. Sta.*)

"open-cored" pomes may become closely connected. These facts will be considered again in the account of fruit development.

It is thus shown by the studies of Kraus that calyx lobes, petals, stamens, and carpels are all outgrowths of the urn-shaped receptacle.

Pollination and Fertilization.—The literature on this subject is extensive. Cross-pollination is the rule and self-pollination the exception in the apple and pear. Experiments have shown that the wind aids but little in cross-

pollination, and that insects, chiefly the honey bee, are relatively more important. The bee is attracted to the flowers by the nectar which is produced rather abundantly.

Self-sterility and Self-fertility.—Many apples and pears are self-sterile, that is, will not fertilize their own pistils. In such cases, pollen from another variety will usually result in fertilization. Self-sterility and self-fertility probably vary with different climatic conditions. In Oregon, it has been found that the Spitzenburg is self-sterile but capable of being fertilized with pollen from a number of other varieties,

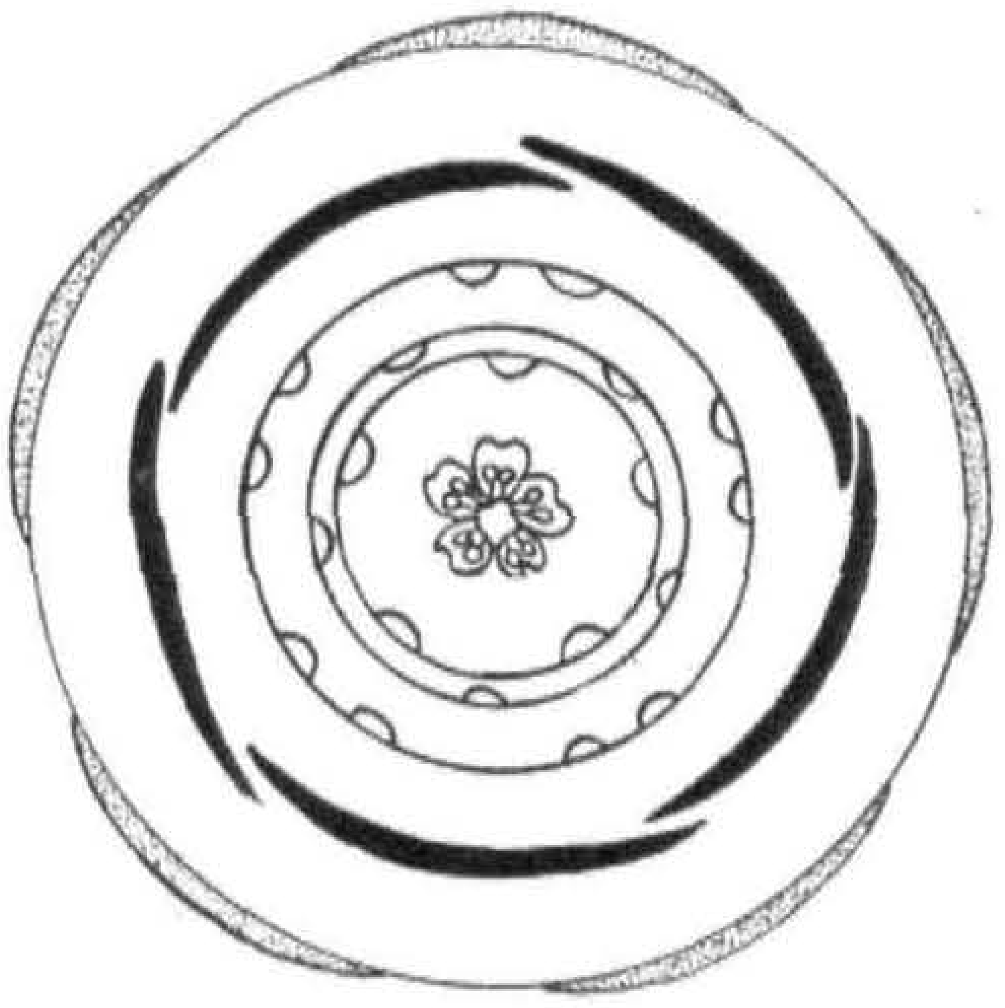


FIG. 160.—Floral diagram of apple (Malus sylvestris). Note that the stamens are in three distinct whorls. (*After Kraus.*)

such as Yellow Newton, Arkansas Black, Jonathan, and Baldwin. Evidently, the mutual affinities of apple varieties must be considered in setting out an orchard. It would not be well to plant solid blocks of Spitzenburg, for example. It should be alternated with rows of some one of the other varieties the pollen of which is capable of fertilizing it. It is no doubt true that the failure of many varieties to set fruit is due, in part, to self-sterility.

Effects of Strange Pollen.—The secondary effects of foreign pollen on the mature fruit have received considerable attention. It is claimed by many that the pollen from one

variety when placed on the stigma of another, immediately impresses its characteristics upon the fruit. It is difficult to understand how foreign pollen could have any considerable effect of this kind. The flesh of the apple is receptacle for the most part. The sperm nuclei of the pollen, of course, do not come into contact with the nuclei of the receptacle cells. It is altogether possible, however, that uniformity of crop,

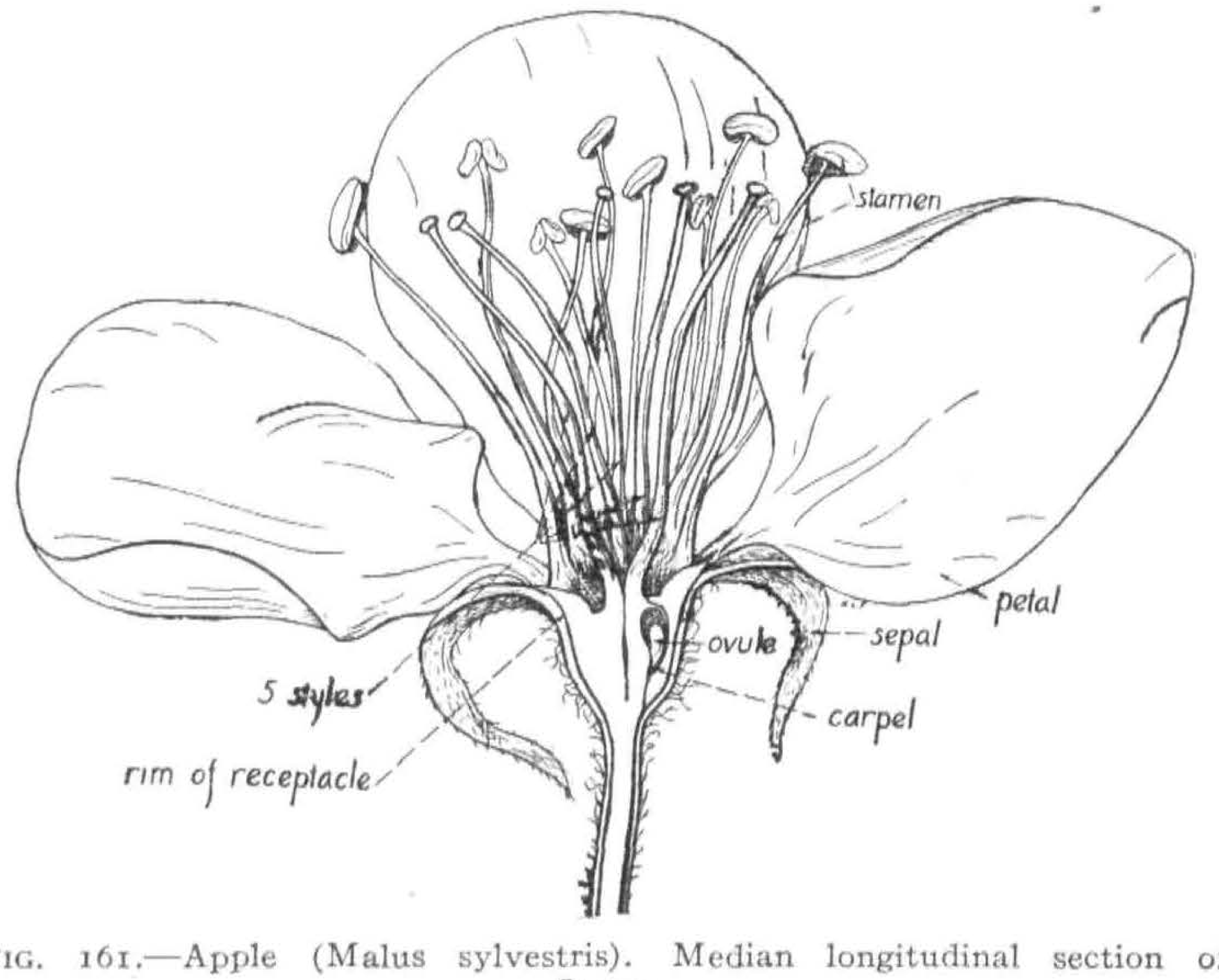


FIG. 161.—Apple (Malus sylvestris). Median longitudinal section of flower.

percentage of set, and size of fruit are immediately affected by strange pollen.

Parthenocarpy.—As a general rule, lack of fertilization of the ovules in the ovary is followed by the shedding of the blossoms; the ovary fails to develop completely if a good number of its ovules are not fertilized. However, development of the ovary does sometimes occur although fertilization fails. Such an unusual development of carpels is called *parthenocarpy*. This phenomenon is not unknown in the

apple. With certain sorts of both apples and pears, fruits weighing 100 grams have been developed without fertilization. Of course, parthenocarpic fruit is seedless. It has been found that parthenocarpic fruits are more prevalent among small fruits than among large fruits of orchard varieties. There are among cultivated plants many which bear seedless fruit. We noted that in the common Mission figs the fruit matures normally without fertilization of the ovules. Seedless tomatoes, egg plants, English forcing cucumbers, oranges, grapes, and bananas are quite common.

The Fruit and Its Development.—*Morphology.*—There are two common opinions as to the nature of pomaceous fruits:

1. Flesh is thickened calyx tube.
2. Flesh is receptacle or torus closely connected with the carpels.

The recent work of Kraus appears to establish the latter. In following through the development of the flower (Fig. 159), it is seen that the receptacle, by more rapid growth at the sides than toward the center, becomes urn-shaped and bears on the rim and inside face, calyx lobes, petals, and stamens. In the development of the fruit, there is a continuation of the enlargement of the receptacle; the throat of the receptacle becomes narrow, and through it the styles protrude; and the connection between receptacle and carpel tissues becomes a very close one; hence receptacle makes up the greater portion of the flesh of the apple.

Ripening Process.—Important chemical changes take place in the ripening process. The content of sucrose (cane sugar) increases steadily in the ripening process up to a maximum and then suddenly decreases. There is a rapid decrease of starch throughout the entire period. Invert sugar (a mixture of glucose and fructose) increases throughout the ripening period while the total sugar increases up to the date when

starch entirely disappears, after which time it fluctuates slightly. Malic acid, which gives the fruit its sourness, gradually becomes less and less. Ripening takes place in two stages. The first stage involves that portion of the fruit within the core line (Fig. 162). Here there is at first a decrease in the starch content just between the locules, at the tips of the carpels. This loss extends outward from these points to the core line. The second stage of the ripening process involves the region outside the core line. At first, streaks free of starch appear in the midst of this area. Soon the middle portion of the area becomes free of starch. There is a gradual increase of this starch-free area, the last regions to ripen being V-shaped areas radiating from the vascular bundles as seen in cross-section. Furthermore, anatomical changes take place in ripening. The middle lamellæ of the cells, soften, resulting in a slight separation of the cells, an increase in the regularity of the cell outline, in the size of intercellular spaces, and amount of intercellular air.

"*Mealiness.*"—This results from a softening of the middle lamellæ; those varieties that are comparatively very mealy have correspondingly weak lamellæ. When a cell divides into two, the common primary wall between them becomes the *middle lamella* of the thicker wall formed by the deposition of material from both protoplasts. Hence in the mature cell wall, the primary or first-formed wall appears as a definite layer between the added layers. Separation of two adjacent cells naturally takes place along this middle line.

Cross-section of Fruit.—In a median cross-section of the apple fruit (Fig. 162), the relation of carpels and receptacle is well made out. The five carpels radiate from the center. Each carpel is composed of a parchment-like endocarp, fleshy mesocarp, and fleshy exocarp. The pith of the receptacle, which is in reality stem, surrounds and unites with the carpels; the pith is without vascular bundles. As a

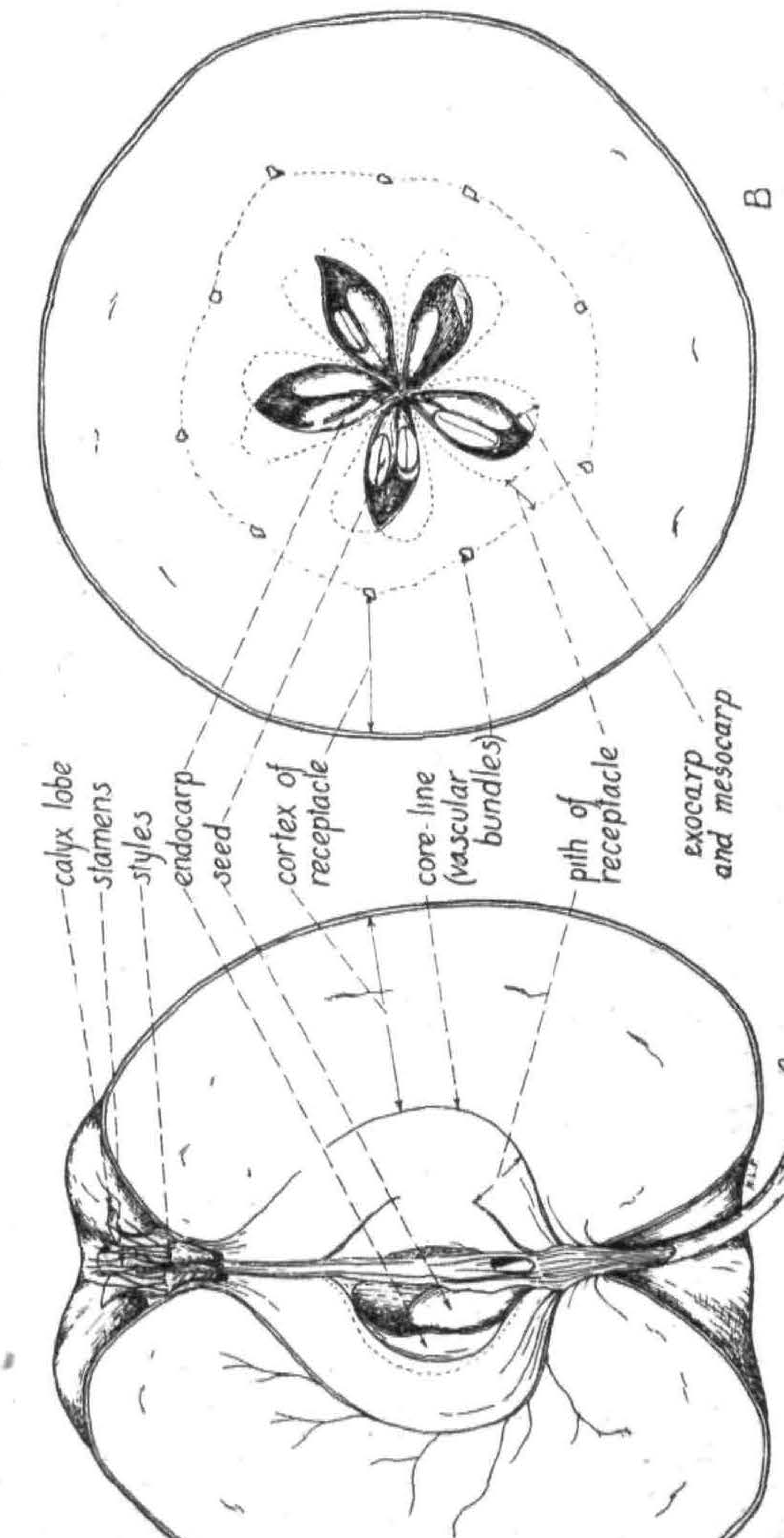


FIG. 162.—*A*, median lengthwise section of mature apple; *B*, cross-section of same.

rule, there are ten primary vascular bundles seen in the median cross-section. They mark the limits of the pith, all tissue outside of them being cortex of the receptacle.

The tissues of the carpels and pith are very similar. However, the tissue of the carpels bears a network of very fine vascular bundles, while that of pith is without such a net work. Many observers have wrongly considered all tissue from parchment-like tissue, surrounding the seed cavities, out to vascular ring, inclusive, as carpellary, whereas others have considered only the parchment-like tissue as carpellary.

The ten primary vascular bundles are related in their development with the carpels, as is shown by the fact that when six carpels occur there are twelve bundles instead of ten, and when there are four carpels, eight bundles. Crandall has noted marked variation in the number of carpels. Large fruits had a number ranging from 4 to 8, while that for small fruits was from 2 to 8. The number of carpels in crab fruits ranged from 2 to 12.

Longitudinal Section of Fruit.—In longitudinal section (Fig. 162), the flesh is seen to be separated into two parts by a distinct line, the "core line." The core line marks the junction of pith and cortex of the receptacle. The primary vascular bundles of the torus follow the core line, and branches from them spread out into the cortex of the fruit. Kraus has demonstrated that apple varieties show marked variation in their internal structure, and that this structure is distinctive for any given variety.

External Characteristics.—These are very important in technical descriptions of the apple. Form is of considerable consequence. In judging form, the apple is held so as to be seen in a line at right angles to an axis from stem end to calyx end. Form terminology includes such terms as round, oblate, conical, ovate, oblong, elliptical, etc. The flower stem persists in the fruit. The depression about the stem

is termed the *cavity*. It varies in shape and depth in the different varieties. At the opposite end from the cavity is the *basin*. This also varies in character and is of taxonomic value in the classification of fruits. The remains of the calyx are persistent within the basin of the common apple. In the pure Siberian Crabs, the calyx is deciduous, while in hybrid forms of Siberian Crabs and the common apple it is partly deciduous. The dried stamens and styles may be seen within the calyx lobes.

The stamens may be *basal*, situated near the base of the calyx tube; *median*, near the middle; or *marginal*, near the outer edge. The calyx tube itself varies in shape from conical to funnel-shaped. The calyx segments, five in number, vary in their arrangement in the mature fruit. They may be *divergent*, that is, reflexed, *erect convergent*, when their margins touch, *flat convergent*, when they are flat and close the tube, and *connivent*, when they are overlapping. In a median transverse section, the "cells" in different varieties vary in shape and relation to the axis of the apple. They may be "open" or "closed," axile or abaxile. When the walls extend to the axis, the cells are axile, and when they are distant from the axis, and unsymmetrical, they are abaxile. When the core line meets inside the calyx tube, the core is said to be *meeting;* if near the calyx tube, it is *clasping*. The core outline varies in shape. There are usually two seeds in each cell cavity; however, there may be more than two or fewer or sometimes none at all. They vary in size and color.

Seed production in apples varies considerably. This variation is seen in an examination of individual fruits as well as of different varieties. Crandall has shown that large fruits produce more seeds than small fruits, that the highly developed orchard varieties produce almost twice as many seeds as the varieties of crabs. He found that seed produc-

tion in large apples exceeded that in small by 14.7 per cent.; the average number of seeds for large apples was 8.27, for small, 7.21, and for crabs, 4.22. The normal number of 10 seeds was found in but 12 per cent. of the large fruits of orchard varieties, whereas 69 per cent. averaged below 10 seeds per fruit, and 18 per cent. above this number.

Key to Principal Species of Malus

Calyx deciduous from the apex of fruit.
- Leaves conduplicate in the bud (Fig. 107); petioles thick, usually about 1 inch long; flowers rose-colored, *Malus floribunda* (flowering crab).
- Leaves convolute in the bud (Fig. 107); petioles slender, usually about 2 to 3 inches long; flowers white or very light rose-colored, *Malus baccata* (Siberian crab).

Calyx persistent on the fruit.
- Leaves glabrous, at least when mature.
  - Leaves prominently lobed, thin, *Malus coronaria* (American crab-apple).
  - Leaves toothed, but not lobed, thick, *Malus angustifolia* (narrow-leaved crab-apple).
- Leaves persistently pubescent or tomentose beneath.
  - Leaves narrowed at base; pomes small, 1 to 1½ inches in diameter.
    - Pedicles slender, 1 to 1½ inches long, *Malus ioensis* (Western crab-apple).
    - Pedicels stout, ½ to 1 inch long, *Malus soulardii* (Soulard crab-apple).
  - Leaves rounded or subcordate at base; pomes large, 2 to 4 inches in diameter *Malus sylvestris* (common apple).

Malus floribunda, *Flowering Crab.*—This is a shrub or small tree, often thorny. The leaves are conduplicate in the bud, the flowers abundant, showy, and rose-red, the fruit red, about the size of a pea, and on slender stalks. It is highly ornamental, and flowers in early spring. It is a native of Japan.

M. baccata, *Siberian Crab.*—This crab is a small, spreading tree with leaves that are convolute in the bud, abundant flowers, usually white and showy, and fruit that is ½ to ¾ inch in diameter, yellow or red, firm and translucent. The species occurs in many forms. The orchard fruits known as "*crab-apples*," are believed to be hybrids between this and the common apple, *M. ylvestris.* The Siberian crab grows wild from Siberia to Manchuria and the Himalaya region.

M. angustifolia, *Narrow-leaved Crab-apple.*—It is a low tree with small, narrow, lanceolate leaves, few-flowered cymes, fragrant pink flowers, and

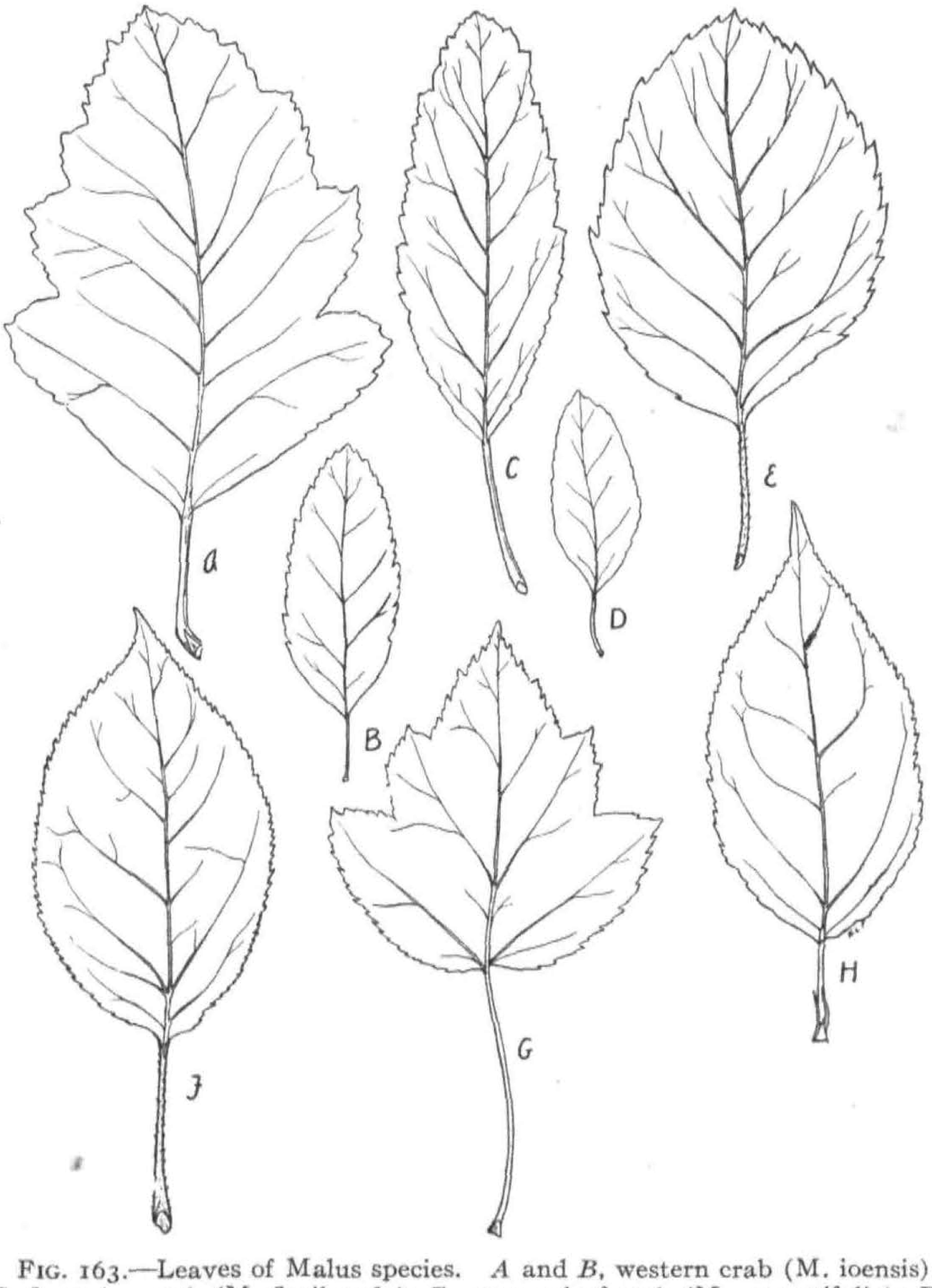


FIG. 163.—Leaves of Malus species. *A* and *B*, western crab (M. ioensis); *C*, flowering crab (M. floribunda); *D*, narrow-leaf crab (M. angustifolia); *E*, Soulard crab (M. soulardi); *F*, common apple (Wealthy) (M. sylvestris); *G*, American crab (M. coronaria); *H*, Siberian crab (M. baccata). × ½.

fruit about 1 inch in diameter. It is distributed from Pennsylvania to Tennessee and Florida.

M. coronaria, American Crab-apple.—This is a small, bushy tree with thorny, crooked branches, ovate or triangular-ovate, sometimes three-lobed, leaves, large flowers, with a persistent calyx, and fruit that is 1 to 1½ inches in diameter, somewhat flattened endwise, greenish-yellow, waxy, fragrant, and rich in malic acid. It grows wild in Ontario and North Atlantic States, west to Kansas and Missouri.

M. ioensis, Western or Prairie States Crab-apple.—It is a small tree with large leaves, firm in texture and of various shapes, large flowers, and green fruit with light-colored spots. It is native of Minnesota, Wisconsin, Illinois, Iowa, Missouri, and Kansas.

Bechtel's Double-flowering Crab is probably a double-flowered form of *Malus ioensis.*

M. soulardii, Soulard Crab.—This is a natural hybrid between the common apple (*M. sylvestris*) and the Western crab-apple (*M. ioensis*). It is a small, stout tree, with leaves similar to those of *M. ioensis*, in close clusters on short, densely wooly pedicels; the fruit is larger and of better flavor than that of *M. ioensis.* It grows wild in the Mississippi Valley.

M. sylvestris, Common Apple.—The common apple is a large tree with twigs and under surface of leaves gray-woolly; the flowers are in close clusters, and on short pedicels; the fruit is very variable. There are numerous varieties differing as to form, size, color, and taste of fruit. In order to keep the varieties true to type, propagation is vegetative rather than sexual.

The common apple is considered to be a native of western Asia and southeastern Europe. In eastern United States, it occasionally escapes from cultivation. It is grown commercially in all parts of the United States except in Florida, the regions bordering the Gulf of Mexico, and warmer portions of the Southwest. The leading apple-growing section of this country is from Nova Scotia south and west to Illinois and Missouri.

The Classification of Apples (*Malus sylvestris*).—There have been a number of systems of classifying cultivated varieties of apples. A brief sketch of the most important of these is given in the American Horticultural Manual Part II, Systematic Pomology. The principal classifications mentioned in the above work are those of Johann Johnston, Germany 1668, Manger, Germany 1780, Dr. Diel, Germany 1792, Diel-Cochnahl, Germany 1855, Diel-Lucas, Germany 1856, John A. Warder, America 1867, John J. Thomas, America 1849, Robert Hogg, England 1876.

The system of Dr. Diel of Germany, was the first to be widely adopted *in toto* or with modifications. He divided the varieties into seven classes, and these into orders. These classes are as follows: Ribbed apples, Rose apples, Rambours, Reinettes, Stripelings, Pointlings, and Flat apples. Beach gives the following groups of varieties: Fall Pippin, Rhode Island Greening, Winesap, Fameuse, Alexander or Aport, Wealthy, Duchess of Oldenburg, Northern Spy, Blue Pearmain, and Ralls-Genet.

Composition.—According to the determinations of Alwood and Davidson, the average amount of juice recovered from summer apples by grinding and pressing is 53.2 per cent.; from winter fruit 53.92 per cent. Crab-apples show an average juice content of 57.31 per cent. The average water content of the whole apple varies from 80 to 86 per cent. of its total weight. It is not possible, of course, to remove all the juice from apples by ordinary pressing, and furthermore, the amount of juice recovered depends upon the grinding and pressing methods. The above workers chemically analyzed the juice and pomace of many varieties. The percentage composition of the juice is shown in the following table:

	Specific gravity	Total solids	Total sugar	Invert sugar	Cane sugar	Acids as H_2SO_4	Tannin
Summer varieties...	1.049	12.33	9.53	5.85	3.50	0.33	0.040
Autumn varieties...	1.054	13.76	10.66	6.93	3.53	0.36	0.069
Winter varieties....	1.056	14.29	11.43	7.04	4.16	0.41	0.050
Crab-apples........	1.062	15.69	11.71	8.08	3.45	0.50	0.122

For vinegar-making, a high sugar content is desirable. A common notion is that acid or "tartar" apples are better for vinegar-making than those low in acid. The amount of acetic acid in a vinegar, which is the important test of its

quality, is dependent upon the amount of sugar in the juice (cider) and not upon the acid. The sour taste of apples is due to the malic acid present. So-called "sweet apples" do not necessarily contain more sugar than "sour apples," but they do contain less acid, hence their "sweetness."

Cider and Vinegar.—Cider is the juice or wine of apples. In the transformation of cider to vinegar, two fermentation processes take place, in the following order: (1) *alcoholic fermentation*, and (2) *acetic acid fermentation*. When cider "begins to work," it is an indication that the first fermentation process is going on. The sugar of the apple juice is being converted into alcohol and carbon dioxide. The escaping of this gas from the fermenting cider causes a "frothing." The process of alcoholic fermentation is produced by a microscopic organism, the yeast plant. When the evolution of carbon dioxide gas has ceased and the alcohol is at its maximum, the cider is spoken of as *hard cider*. The second step in vinegar-making is the conversion of the alcohol of the hard cider into acetic acid. This change is brought about by a bacterium, the acetic acid germ. The characteristic properties of vinegar are due to acetic acid.

Dried Apples.—The output of dried apples in the United States in 1909 was 44,000,000 pounds. Many housewives dry their apples in the sun. When apples are dried on a large scale, they are peeled, cored, and sometimes sliced by machinery. The fruit is then dipped for a few minutes in a weak salt solution, which tends to prevent discoloration. It is then placed in trays and taken to the drying machine. It is the practice in some manufacturing plants to subject the apples, before drying, to sulphur fumes for a short time. These fumes bleach the apples slightly, and also kill any organisms that may be present. The most common drying method is to pass hot air under high pressure over the fruit. After removal from the drying machine, the apples are

allowed to sweat for several days either in the open air or in well-ventilated chambers. They are then ready for packing.

Production of Apples in the United States.—In 1919 there were produced 136,560,997 bushels of apples in this country. The ten leading States in the order of their production were Washington, New York, Virginia, California, Arkansas, Oregon, Michigan, Pennsylvania, and Missouri.

PYRUS (Pear)

The characters of this genus are very similar to those of *Malus*. The pears are trees or shrubs with simple leaves, and large flowers in terminal cymes, resembling those of the apple; the styles are usually free to the base. The fruit is a pome, varying in shape, with five carpels, two seeds in each cavity, and an abundance of grit cells in the flesh (Fig. 164).

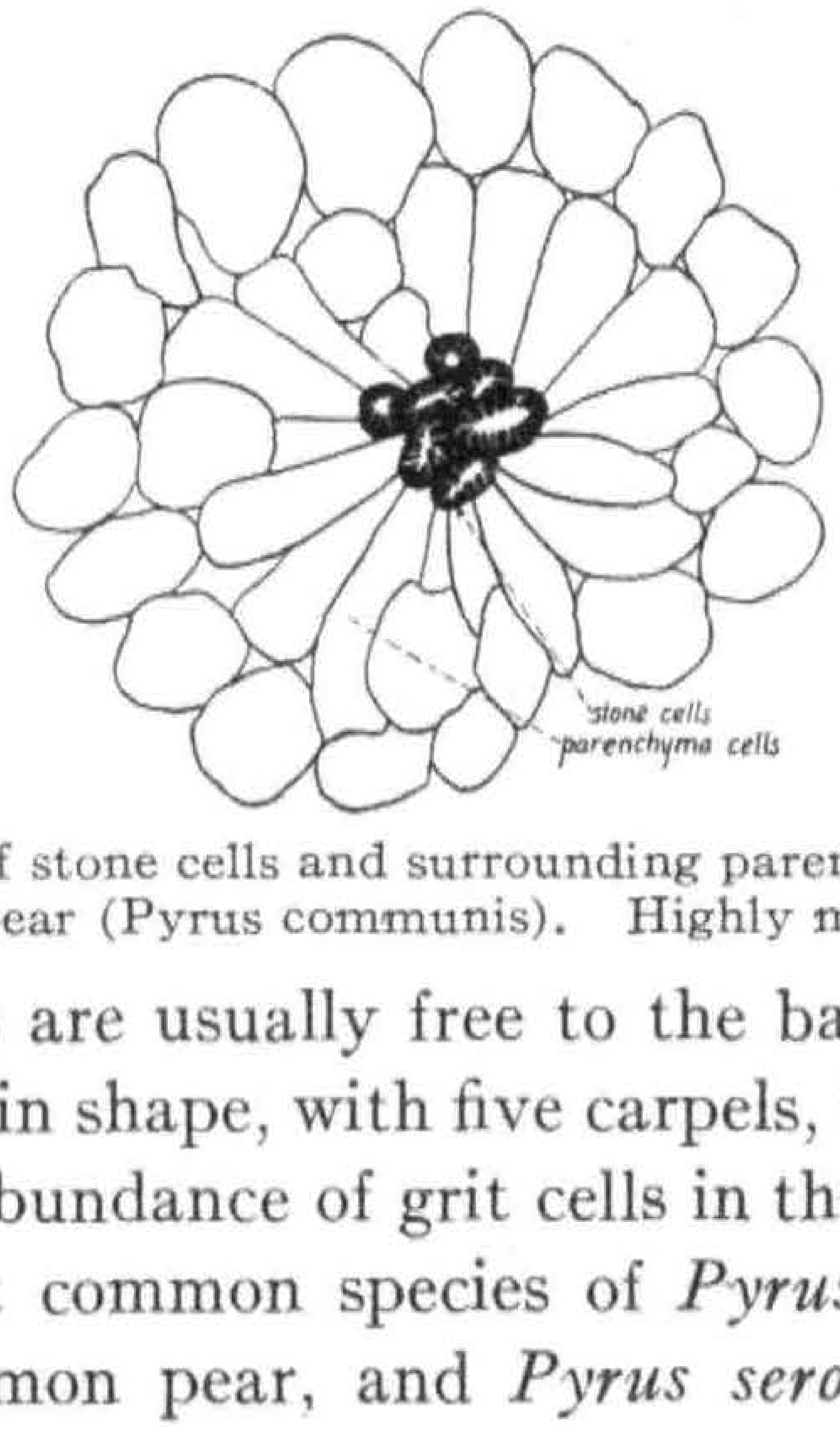


FIG. 164.—A group of stone cells and surrounding parenchyma cells from the flesh of pear (Pyrus communis). Highly magnified.

The two most common species of *Pyrus* are *Pyrus communis*, the common pear, and *Pyrus serotina culta*, sand, Japanese, or Chinese pear.

In the common pear, the teeth on the leaves are obtuse, the flowers appear with the leaves, and the calyx is persistent, while in the Japanese or Chinese pear, the teeth on the leaves are sharp-pointed or bristle-like, the flowers appear before the leaves, and the calyx is deciduous.

PYRUS COMMUNIS (Common Pear)

Stem.—The common pear is a tree of upright-growing habit. The *flower buds* are mixed and terminal, as in most apples. Paddock and Whipple have shown that, in Colorado at least, the Anjou pear may produce blossom buds on one-year-old spurs; that Bartletts may form bloom on the end of the last year's growth; that Anjou, Bartlett, Duchess, and Kieffer varieties produce bloom in axillary buds on the last year's growth, and that a number of varieties, as Anjou, Bartlett, Duchess and Sheldon, are annual bearers. There are usually from six to nine flowers in a bud. The "*spurs*" are similar in appearance and development to those of the apple.

Leaves and Flowers.—The *leaves* are ovate, elliptic, and finely toothed. The *flowers* are in simple terminal cymes; the pedicels are 2 to 3 inches long, and appear with the leaves; the *petals* are five in number, rounded, short-clawed, and usually white; the *sepals* are persistent; the *styles* are distinct to the base.

Fruit.—The *fruit* varies in shape, usually tapering to the base; the flesh is with grit cells (Fig. 164) (groups of stone cells imbedded in parenchyma).

Geographical.—The common pear is probably a native of southern Europe and Asia. It is the pear of history, referred to in the literature of Egypt, Syria, Greece and Rome. In many localities, it has escaped from cultivation. There are numerous cultivated varieties. The pear thrives best in the northern half of the United States.

PYRUS SEROTINA CULTA (Sand, Japanese, or Chinese Pear)

This is a strong-growing tree with dark green shining, broad-ovate, long-pointed leaves that are very sharply toothed. The large flowers appear before the leaves. The fruit is hard and russet-like, keeps well, and has a deciduous calyx.

The tree is a native of China and is found wild in Japan. Chinese Sand, Madame von Siebold, Mikado, and Japanese Sand are a few of the varieties grown in the United States. It is also often used to hybridize with our common pear, the Kieffer variety and the Pineapple pear being the best-known ones resulting from such a cross.

Self-sterility in Pears.—Much of the barrenness in pear orchards is due to self-sterility, that is, the inability of the pollen of a variety to fertilize the ovules in the pistils of that variety. It has been frequently observed in many portions of the country that when a certain variety of pear, as well as other fruits, was planted thickly, there was often pronounced self-sterility. This is particularly true, it seems, of Bartlett and Kieffer pears. There has been obtained the following average results, under Virginia conditions, in self-fertilizing Bartlett, and in crossing with a number of varieties (in the table, the last mentioned variety of a cross furnished the pollen):

Pollinations	Av. number of blossoms set	Av. weight of mature fruit, ounces
Bartlett × Bartlett	1 in 513	2.00
Bartlett × Kieffer	1 in 10	3.00
Bartlett × Anjou	1 in 7	3.75
Bartlett × Lawrence	1 in 9	3.50
Bartlett × Duchess	1 in 10	3.50

The following table shows similar relations in the case of Kieffer pears:

Pollinations	Av. number of blossoms set
Kieffer × Kieffer	1 in 253
Kieffer × Bartlett	1 in 5
Kieffer × Le Conte	1 in 7
Kieffer × Lawrence	1 in 6
Kieffer × Duchess	1 in 5
Kieffer × Anjou	1 in 4
Kieffer × Clairgeau	1 in 3
Kieffer × Garber	1 in 7

From these experiments, Fletcher recommends (under Virginia conditions, at least) that Anjou, Lawrence, Duchess and Kieffer are desirable varieties to plant with Bartlett, and that Bartlett, Le Conte, Garber, Lawrence, Duchess, Anjou, and Clairgeau are desirable varieties to plant withthe Kieffer.

It is not probable that the same degree of self-sterility for a given variety will prevail under different climatic and soil conditions. Furthermore, it must be held in mind that no immediate effect of strange pollen need be expected in the resulting fruit.

Dwarf Pears.—The pear is the most common tree grown in a dwarf form in the United States. The usual method of dwarfing pears is to graft them on quince roots, which are very slow-growing.

In a graft, the two plants retain their individuality to a large degree. However, there are numerous instances cited of the influence of the stock upon the scion, or scion upon the stock.[1] When pears are grafted on the more slowly growing roots of the quince, the stock in this case retards the growth of the pear, and dwarfing results. The common quince used in Angers and the varieties ordinarily dwarfed are Angouleme, Bartlett, Anjou, and Louise Bonne. Dwarfing appears to improve the quality of the fruit.

CYDONIA (Quince)

The genus has much the same characters as *Malus* and *Pyrus*, except that each of the five carpels has several seeds

[1] If the common apple is grafted on the wild crab, the fruit of the scion growth is more sour than usual. Late varieties of apple may mature earlier when grafted on early stock. The influence of the scion upon the stock is well shown in the case of grafting the morning glory, an annual, upon the sweet potato, a perennial. In this case, the tuberous roots develop much earlier than usual. A most interesting illustration is the development, in Abutilon, of leaves with white spots (albescent leaves) on a green leaved scion when grown as a graft upon an albescent stock.

covered with a mucilaginous pulp, and the large flowers are in small clusters or sometimes single at the tips of branches.

There are several species of *Cydonia*, the most common being *C. oblonga* (edible quince).

CYDONIA OBLONGA (Common Quince)

Stem.—The common quince is a small tree seldom over 15 feet high, or a shrub, with rather crooked, slender branches. The shoots that come from axillary buds and those that come from terminal buds may give rise to flower-bearing shoots, but it is usually the case that the largest fruit comes on branches arising from axillary buds on the last half of the annual growth. The flowers are not from fruit buds formed in the autumn; after a woody shoot has grown several inches, a flower is produced which terminates the season's growth of that shoot.

Leaves.—The leaves are alternate, with blades 2 to 3 inches long, oval, somewhat heart-shaped or rounded at the base, acute at the apex, green above and soft-hairy beneath, and with petioles about ½ inch long.

Flowers.—As a rule, the flowers are solitary; the *petals* are white or light pink; the *stamens* are numerous; there are five *carpels* with several ovules in each cavity.

Fruit.—The fruit may be apple- or pear-shaped, hard, woolly when young, becoming smooth with age; the flesh is free of grit cells; the skin is yellow at maturity; each of the five cells of the ovary contains several seeds which have a mucilaginous coating.

Varieties.—Bailey gives five varieties of the species, *Cydonia vulgaris: Lusitanica, maliformis, pyriformis marmorata,* and *pyramidalis.*

Uses.—Quinces are not usually eaten raw but made into marmalades, or canned. The juice is sometimes employed to flavor manufactured fruit products.

References

ALWOOD, WILLIAM B., and DAVIDSON, R. J.: The Chemical Composition of Apples and Cider. U. S. Dept. Agr. Bur. Chem. Bull. 88: 7–18, 1904.

BEACH, S. A., BOOTH, N. O., and TAYLOR, O. M.: The Apples of New York. 22d Ann. Rept. N. Y. Agr. Exp. Sta., vol. 1: 1–409; vol. 2: 1–360, 1903.

BIGELOW, W. D., GORE, H. C., and HOWARD, B. J.: Studies on Apples. U. S. Dept. Agr. Bur. Chem. Bull. 94: 1–100, 1905.

BLACK, CAROLINE A.: The Nature of the Inflorescence and Fruit of Pyrus malus. Mem. N. Y. Bot. Gardens, 6: 519–547, 1916.

BRADFORD, F. C.: The Pollination of the Pomaceous Fruits. II. Fruit-bud Development of the Apple. Ore. Agr. Exp. Sta. Bull. 129: 1–16, 1915.

BROOKS, CHAS.: The Fruit Spot of Apples. Bull. Torrey Bot. Club, 35: 423–456, 1908 (includes notes on structure of fruit).

BUDD, J. L., and HANSEN, N. E.: American Horticultural Manual. Part II, Systematic Pomology. John Wiley & Sons, 1911.

BUTLER, O.: On the Cause of Alternate Bearing in the Apple. Bull. Torrey Bot. Club, 44: 85–95, 1917.

CHITTENDEN, F. J.: Pollination in Orchards. III. Self-fruitfulness and Self-sterility in Apples. Jour. Hort. Soc., 39: 615–628, 1914.

CRANDALL, C. S.: Seed Production in Apples. Ill. Agr. Exp. Sta. Bull. 203: 185–213, 1917.

COX, H. R.: Oriental Pears and Their Hybrids. Cornell Agr. Exp. Sta. Bull. 332, 1913.

DECAISNE, JOSEPH: Memoire sur la famille des Pomacees. Nouvelles Archives du Museum, X, pp. 113–192 (Paris), 1875.

Le jardin fruitier du museum, un iconographie de touts les especes et varietes d'arbres fruitiers cultives dans cet etablissement. Firmin Didot Freres.

DRINKARD, A. W.: Fruit-bud Formation and Development. Rept. Vir. Agr. Exp. Sta., 1909–1910: 159–205, 1911.

EWERT, K.: Die Parthenokarpie der Obstbaume. Ber. Deut. Bot. Gesell., 24: 414–416, 1906.

Die Parthenocarpie der Obstbaume. Ber. Bot. Ges., 26: 414–416, 1906.

FLETCHER, S. W.: Pollination of Bartlett and Kieffer Pears. Reprint from Ann. Rept. Va. Agr. Exp. Sta., 1909: 212–232.

Pollination of Bartlett and Kieffer pears. Ann. Rept. Va. Agr. Exp. Sta., 1909 and 1910: 213–224, 1911.

GOFF, E. S.: The Origin and Early Development of the Flowers in the Cherry, Plum, Apple and Pear. 16th Ann. Rept. Wis. Agr. Exp. Sta., 290–303, 1899.

Investigations of Flower Buds. 17th Ann. Rept. Wis. Agr. Exp. Sta., 266–285, 1900.

Investigation of Flower Buds. 18th Ann. Rept. Wis. Agr. Exp. Sta. 304–316, 1901.

Origin and Development of the Apple Blossom. Am. Gard., 22: 330 and 346–347, 1901.

GARDNER, V. R., WAGNESS, J. R., and YEAGER, A. F.: Pruning Investigations. Oregon Agri. Exp. Sta. Bull. 139: 1–88, 1916.

GOURLEY, J. H.: Studies in Fruit Bud Formation. N. H. Agr. Exp. Sta., Tech. Bull. 9: 1–79, 1915.

HARDY, J. A., and A. F.: Traité de la taille des arbres fruitiers, ed. 12, 123, Paris.

HEDRICK, V. P.: Dwarf Apples. N. Y. Agr. Exp. Sta. Bull. 406: 341–368, 1915.

Pears of New York. 1921.

KRAUS, E. J.: The Pollination of the Pomaceous Fruits. I. Gross Morphology of the Apple. Ore. Agr. Exp. Sta. Res. Bull. I, pt. I: 1–12, 1913.

The Study of Fruit Buds in Oregon. Ore. Agr. Exp. Sta. Bull. 130: 12–21, 1915.

Variation of Internal Structure of Apple Varieties. Ore. Agr. Exp. Sta. Bull. 135: 3–42, 1916.

KRAUS, E. J., and RALSTON, G. S.: The Pollination of the Pomaceous Fruits. III. Gross Vascular Anatomy of the Apple. Ore. Agr. Exp. Sta. Bull. 138: 4–12, 1916.

LEWIS, C. I., and VINCENT, C. C.: Pollination of the Apple. Ore. Agr. Exp. Sta. Bull. 104: 1–40, 1909.

MCALPINE, D.: The Fibro-vascular System of the Apple and its Function. Proc. Linn. Soc., N. S. Wales, 36: 613–625, 1911.

The Fibro-vascular System of the Quince Fruit Compared with That of the Apple and Pear. Proc. Linn. N. S. Wales, 37: 689–697, 1912.

PADDOCK, W. and WHIPPLE, O. B.: Fruit Growing in Arid Regions. MacMillan Co., 1910.

PICKETT, B. S.: Factors Influencing the Formation of Fruit Buds in Apple Trees. Trans. Mass. Hort. Soc., pt. I: 57–72, 1913.

SANDSTEN, E. P.: Some Conditions Which Influence the Germination and Fertility of Pollen. Wis. Agr. Exp. Sta. Research Bull. 4: 149–172, 1909.

SHAW, J. K.: The Technical Description of Apples. Mass. Agr. Exp. Sta. Bull. 159: 73–90, 1914.

Leaf Characters of Apple Varieties. Mass. Agr. Exp. Sta. Bull. 208: 21–31, 1922.

WAITE, W. B.: The Pollination of Pear Flowers. U. S. Dept. Agr. Div. Veg. Path. and Phys. Bull. 5: 1–110, 1894.

WEST, G. H.: The Pollination of Apples and Pears. Trans. Kans. State Hort. Soc., 32: 38–50, 1912.

CHAPTER XXVIII

DRUPACEÆ (Plum Family)

Habit of Growth, Stems.—Representatives of the plum family are trees or shrubs. The bark exudes a gum, and the leaves, bark, and seeds are bitter, and contain prussic acid. Many cases of poisoning have been recorded from eating the seeds of peach and bitter almond, and it is also known that stock is poisoned from eating the leaves of wild cherries. The glucoside, amygdalin, acted on by emulsin, an enzyme, in the presence of water is changed to prussic acid, grape sugar, and benzaldehyde. Prussic acid is deadly poisonous even in small amounts.

FIG. 165.—Leaf of peach (Amygdalus persica). The base of the leaf considerably enlarged, in *B*.

Leaves.—The leaves are alternate, petioled and commonly finely toothed. The teeth and petiole are often glandular (Fig. 165); the stipules are early deciduous.

Flowers.—The perfect, regular flowers (Fig. 166) are solitary (apricot), or in racemes (wild black cherry, etc.), umbels (sweet cherry, etc.), or corymbs (perfumed cherry). The *calyx* is free from the ovary, five-lobed, bell-shaped or tubular and with its lobes

imbricated in the bud; the *corolla* has five distinct petals; there are numerous *stamens.* In a longitudinal section

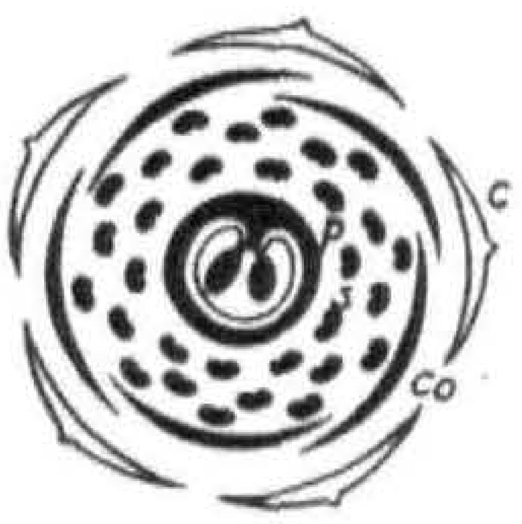


FIG. 166.—Floral diagram of Prunus.

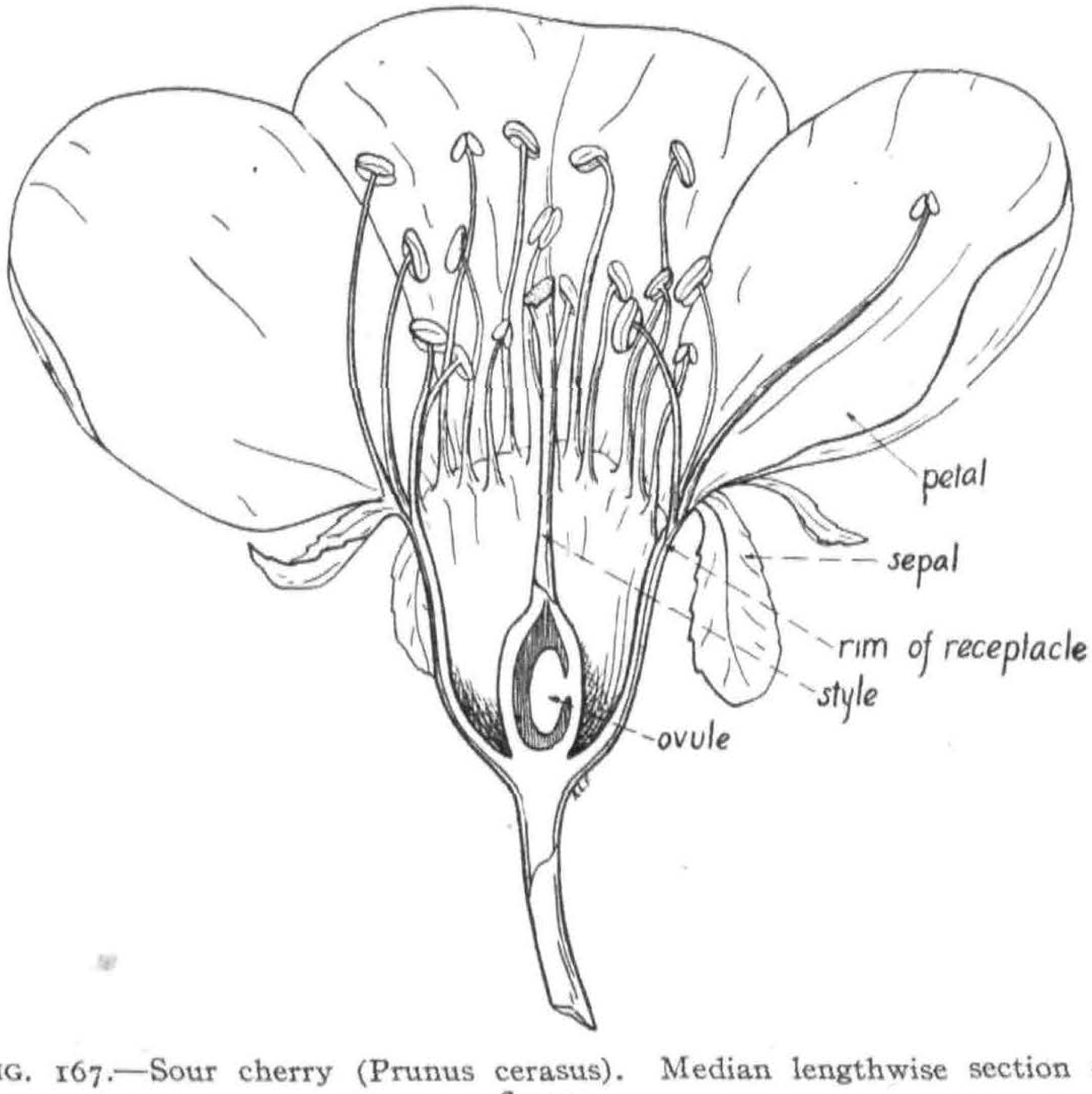


FIG. 167.—Sour cherry (Prunus cerasus). Median lengthwise section of flower.

(Fig. 167) of the drupaceous flower, it is seen that the ovary is placed down within a cup commonly called the "calyx tube." If it is a calyx tube, then petals and stamens are

inserted upon it. It is very probable that this tube is receptacle and that calyx, corolla and stamens are mounted thereupon. There is one *pistil*, situated at the bottom of the hollow receptacle; the *ovary* is one-celled and two-ovuled; the style is single and terminal and bears a small, head-shaped stigma.

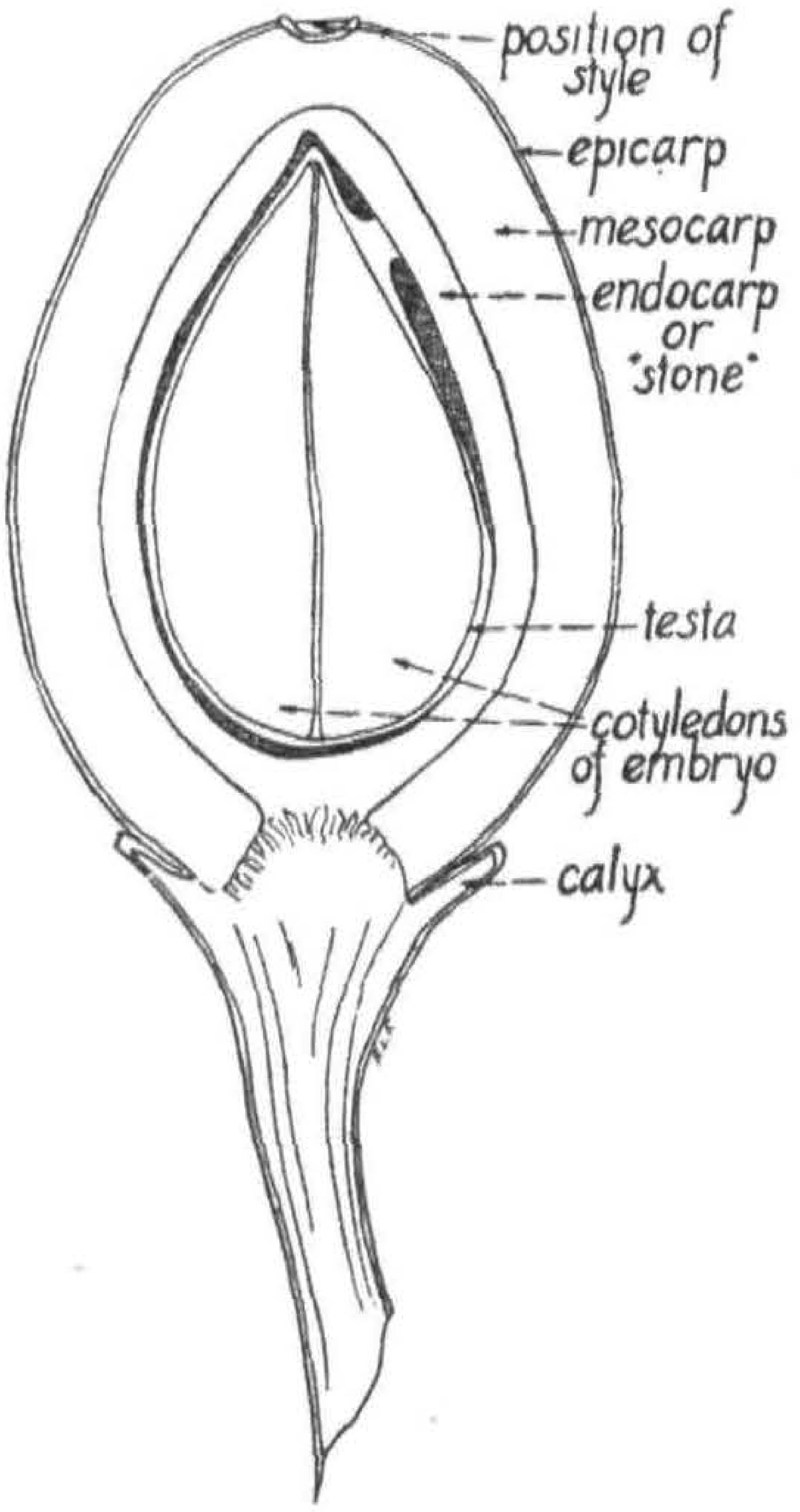


FIG. 168.—Median lengthwise section of young cherry fruit (drupe).

Fruit.—The fruit is a drupe (Fig. 168), that is, one with a single seed surrounded by a stony endocarp, fleshy mesocarp, and an outer skin or exocarp (epicarp). However, if one examines the young ovary of a *Prunus* flower he will find two ovules; one of them aborts, the other develops into a seed. The endosperm is absent, or present only in a small amount. The cotyledons are fleshy.

The only genus of any importance is *Prunus*. It has the characteristics of the family.

PRUNUS

This genus includes the plum, cherry, almond, peach and apricot. These main groups may be distinguished by the following key:

Key to Main Groups of Genus Prunus

Stone smooth.
  Flowers clustered; fruit glabrous.
    Fruit large, usually grooved, covered with a bloom; stalk short; stone usually compressed, longer than broad; leaves convolute in the bud (Fig. 107), *Plums*.
    Fruit small, usually not grooved, not covered with a bloom; stalk long; stone usually globular; leaves conduplicate in the bud (Fig. 107), *Cherries*.
  Flowers solitary or in two's; fruit velvety at first, *Apricots*.
Stone pitted or furrowed.
  Flesh soft, thick, juicy, *Peaches*.
  Flesh hard, thin, dry, *Almonds*.

The genus has about 90 species, nearly all of which occur north of the equator; they are widely distributed in both eastern and western hemispheres. Most species are confined to the temperate zone. The evergreen cherries include a group found in the tropics and subtropics.

PLUMS

Stems.—The plums are shrubs or small trees. The different species vary considerably in bark and twig characters. The bark of southern forms is lighter in color than that of those growing in the north. Plums have a tendency to produce spurs (Fig. 169). Flower buds are, as a rule, on these spurs, one spur bearing from 2 to 20 buds. The spur may terminate in a leaf bud. However, in most plums, true terminal buds are seldom formed. In such cases, if the last

lateral bud is a branch bud, this continues the growth of the branch in a straight line. The line between the two seasons' growths is not as sharp, in this case, as when a terminal bud develops. If the last lateral bud is a flower bud, the twig usually dies back to the lateral branch developed from the last branch bud. In all plums, the flower buds are lateral. Flower buds usually stand out at an angle of about 30°, while leaf buds are more appressed to the stem.

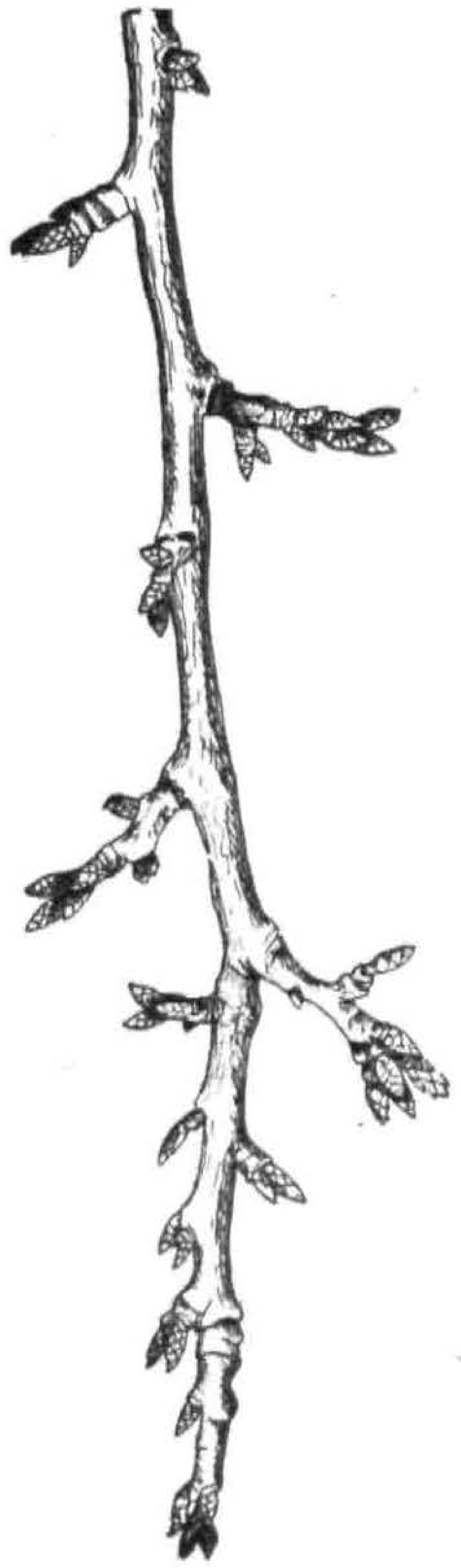


FIG. 169.—Twig of Domestica plum (Prunus domestica). (*After Paddock and Whipple.*)

Leaves.—The leaves of plums vary a great deal in size, form, color, surface, thickness, and margin. In some species, the serrations are tipped by glandular prickles. Stipules are present. The leaves are convolute in the bud (Fig. 107).

Inflorescence.—The flower buds of the plum, unlike those of the apple and pear, bear only flowers. They may break open before, simultaneously with, or after the leaf buds. The flowers are in fascicled umbels. The number of flowers in the bud varies from one to five, two and three being the most common numbers.

Flowers.—The receptacle forms a hollow cup (Fig. 167). On its edge, are arranged five sepals, five petals, and fifteen to twenty stamens. There is a single pistil bearing one style and one stigma. The pistil is at the bottom of the receptacle. There are two ovules in the young ovary; one of them aborts during maturation of the fruit.

Fertilization.—Many of the plums are practically self-sterile. This is due to the impotency of the pollen when used on the stigma of the same flower. The native plums exhibit the greatest self-sterility. Japanese and domestic plums are less self-sterile than native species. In some cases, not only are pistils developed that are so weak as to fail even if pollinated, but some flowers do not form pistils. Again, pistils and stamens of the same flower often mature at different times. Usually, the pistils mature first. Hence it is seen that cross-fertilization is very necessary in plum orchards, and not only cross-fertilization between different trees of the same variety but between different varieties. It is reported that French and sugar prunes in California set a very light crop unless a large number of bees are present in the orchard at the time of blooming. They appear to be self-sterile to some extent. Imperial prune trees that were enclosed in a tent from which all insects were excluded set no fruit. It seems that, with the Imperial prune, fruit is not set unless pollen is brought from other trees. All *Prunus* species are insect-pollinated for the most part.

Fruit.—After fertilization, the receptacle, with its attached sepals, petals, and stamens, is cut off by a circular abscission layer near its base (Fig. 168). The ovary wall increases in thickness to form the following fruit parts (Fig. 168): (1) skin, *exocarp;* (2) flesh, *mesocarp;* and (3) hard stony layer about the seed, *endocarp*. The style and stigma do not persist in the fruit. The seed is within the endocarp. Hence the *stone* ("pit") of the plum consists of hardened endocarp, seed coat, and embryo. The stone is compressed.

Classification of Plums.—For a complete description of the species of plums in American plum culture, see "The Plums of New York;" Hedrick, Report of the N. Y. Agr. Exp. Sta., vol. 3, pt. II, 1911; and Wight, W. F., "Native American Species of Prunus," Bull. 179, B. P. I., 1915.

KEY TO PRINCIPAL SPECIES OF PLUMS[1]

Flowers in clusters of one or two (three in *P. triflora*), OLD WORLD PLUMS.
Shoots and pedicels pubescent.
Fruits large, more than 1 inch in diameter, variable in shape, often compressed; tree large; stamens about 30, *P. domestica.*
Fruits small, less than 1 inch in diameter, uniformly oval or ovoid; tree small, compact; stamens about 25, *P. insititia.*
Shoots glabrous or soon becoming so, pedicels glabrous.
Flowers mostly single, *P. cerasifera.*
Flowers in threes, *P. triflora.*
Flowers in clusters of three or more, rarely two, AMERICAN PLUMS.
Leaf serrations glandless, acute; calyx lobes entire, glabrous on the outer, pubescent on the inner surface, not glandular, *P. americana.*
Leaf serrations glandular (at least when they first unfold), rounded or obtuse; calyx lobes glandular (except in *P. angustifolia*).
Leaves broad, mostly oblong-ovate or obovate, the margin often doubly serrate; flowers 2 to 2.5 centimeters broad; calyx with a reddish tinge, at least when old, the lobes glandular serrate, *P. nigra.*
Leaves narrow, ovate, ovate-lanceolate, the margin rarely doubly serrate; flowers 8 to 15 millimeters broad; calyx rarely reddish, the lobes entire, either glandular or glandless.
Leaves thick, slightly lustrous on upper surface; veins conspicuous below; margin coarsely and irregularly serrate, *P. hortulana.*
Leaves usually thin, lustrous on upper surface, veins not conspicuous below, margin finely and evenly serrate.
Leaves usually 6 to 10 centimeters long; calyx lobes glandular, *P. munsoniana.*
Leaves 2 to 6 centimeters long; calyx lobes glandless, *P. angustifolia.*

DISCUSSION OF SPECIES

Prunus domestica.—This is a vigorous-growing tree which may reach a height of 30 or 40 feet. The leaves are ovate or obovate, elliptical or oblong-elliptical; the upper surface is smooth, the lower often finely hairy, the margins coarsely toothed, and the teeth often glandular. The flowers usually appear after the leaves, sometimes with them. The fruit is generally globular, the skin varies in color, the flesh is yellowish, and the stone free or clinging.

[1] Adapted from The Plums of New York by Hedrick.

This is the best known and most widely distributed species of plums. It has been cultivated for 2,000 years, originally coming from about the Caucasus Mountains. The first colonists brought varieties of this species to North America. There are now over 950 varieties of Domestic plums grown in this country. These have been divided into a number of groups, largely based upon fruit characteristics. These groups are as follows:

1. *Green Gages* (Reine Claude).—These are low trees with dark bark which cracks deeply, with leaves doubly toothed, fruit relatively small, round, mostly green or golden, and of excellent quality. The stone is either free or clinging. Important varieties are Reine Claude, Bavay, Spaulding, Yellow Gage, Washington, etc.

2. *Prunes.*—A prune is any plum that can be cured without removing the pit. All plums with a large percentage of sugar make good prunes. The fruit is large, oval, usually compressed, blue or purple, and with a firm, greenish, yellow, or golden flesh, and free stone. Prunes are raised on the Pacific Coast. The industry there has become a large one. Important varieties are Italian, German, Agen, Tragedy, Tennant, Sugar, Giant, Pacific, and Ungarish.

Preparation of Prunes.—In the preparation of prunes, the plums are first cleaned, and their skins ruptured to permit of more rapid drying. Usually, they are dipped into boiling water or hot lye, which not only cleans but also cracks the skin. They are then dried in the open sun, or in drying sheds where artificial heat may be utilized. After drying, the prunes are allowed to "sweat" for two or three weeks. They are then graded and "glossed" or finished by heating in steam or immersing in salted boiling water, glycerine or fruit juice. This gives the surface of the prunes a shiny appearance, and also sterilizes the exterior.

3. *Peridrigon Plums.*—This is a prune plum grown only in France.

4. *Yellow Egg Plums.*—The fruit of these is large, in fact the largest of plums, long-oval and has a yellow or purple skin, and yellow flesh. Well-known varieties are Yellow Egg, Red Magnum Bonum, Golden Drop, and Monroe.

5. *Imperatrice Plums.*—These are medium-sized, dark blue plums, with thick skin, firm flesh, and clinging stones. Such varieties as Ickworth, Arch Duke, Monarch, Shipper, Arctic, etc., belong to this group.

6. *Lombard Plums.*—This group includes the reddish or mottled varieties of Domestic plums. Lombard, Bradshaw, Victoria, Pond, and Duane are well-known varieties.

Prunus insititia.—This is a small tree not over 25 feet high with small ovate or obovate, finely toothed leaves which are usually glandular; both surfaces of the leaves are slightly hairy. The flowers are usually in lateral, umbellate clusters. The fruit is globular or oval, small, usually bluish black or golden yellow, and has yellow flesh, and a clinging or free stone.

Varieties of this species are hardy and thrifty. The species has been in cultivation over 2,000 years, but in all that time has shown but little variation. Insititia plums rank second to Domesticas. The species grows wild from the Mediterranean northward into Norway, Sweden and Russia. Insititia plums fall into four groups as follows:

1. *Damsons.*—These are spicy plums, mostly sour, and much desired for preserving.

2. *Bullaces.*—This group contains a few varieties differing but little from the preceding group, except as to fruit shape. The Bullaces are spherical.

3. *Mirabelles.*—These are round, yellowish or golden plums with a free stone and resemble much the green gages as to quality.

4. *St. Juliens.*—This is a name applied to a group of plums resembling the Damsons. They were formerly used in this country as stocks.

Prunus cerasifera.—These are the cherry or Myrobalan plums. They are hardy, thrifty varieties, free from disease, readily adaptable and most suitable for hybridizing. The trees are small, bloom profusely, and bear a small, round, cherry-like plum from ½ to 1 inch in diameter. They are adapted to ornamental usage They are also used as stocks upon which to budother plums.

Prunus triflora.—These are the Japanese plums; they are not cultivated in many parts of the world. They are native of China. It is a highly adaptable group, vigorous, productive, early-bearing, and disease-free. Varieties are, for the most part, *cling stones.*

Prunus americana.—This is our most important native plum. It grows wild from New Mexico to Manitoba, and eastward to the Atlantic Coast. Not being able to raise European plums in the Mississippi Valley, Americans domesticated the native American plum. Varieties of this species are hardy. The American plum tree is usually small, with rough, shaggy bark. The fruit is reddish or yellowish. Altogether, there are about 260 varieties of the *americana.* Waugh finds that they often bear defective pistils or stamens, or that they are often protandrous or protogynous. From his observations, he recommends some provisions for cross-fertilization when planting *americanas.*

Prunus hortulana.—This species includes a number of plums well suited for jelly, preserves, and spicing. They are very free of suckers. Important varieties are American, Golden, Juicy, Ruby, Waugh, and Gonzales. The *Hortulanas* are adapted to the Southern States.

Prunus nigra.—This is the most northern of American plums. It is well adapted to the States along the Canadian border.

Prunus munsoniana.—This is the plum most grown in the South. The varieties are mostly cling stones. Of all plums, these are most in need of cross-pollination. A few of the chief varieties are Robinson, Newman, Wild Goose, Arkansas, and Downing.

Prunus angustifolia.—The Chickasaw plum is a small tree, 6 to 10 feet high, sometimes shrubby. The fruit is small, almost globular, flesh yellow, and of good quality. It ranges from Delaware to Louisiana and westward to Arkansas and Texas. Its varieties do well in the Southern States.

The two subspecies, *watsoni* and *varians,* have varieties of some horticultural value, such as Purple Panhandle, African, Clark, Emerson, etc.

CHERRIES

Description.—The cherries resemble plums in many respects. The bark of the cherry separates in rings. The *flower buds* are usually found on short spurs (Fig. 170). In

some sour cherries, however, axillary flower buds occur on long, strong shoots. These buds produce fruit the following spring. Since the lateral buds in such shoots are flower-bearing, no lateral branches are produced, and the result is a long, naked branch. On the spurs, the flower buds are axillary and a branch bud terminates the short shoot.

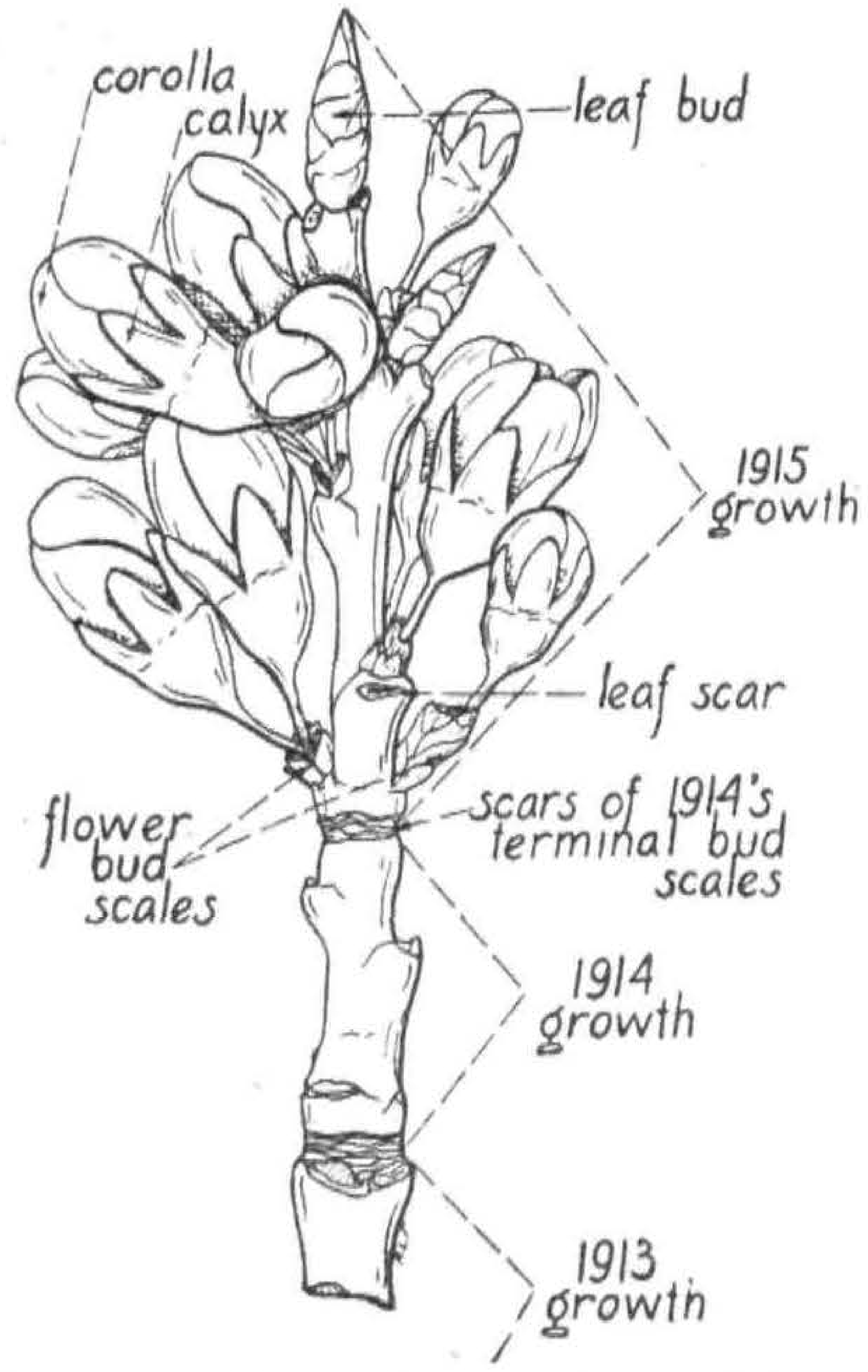


FIG. 170.—Spur of sour cherry (Prunus cerasus).

The *flower buds* bear only flowers and no leaves (except very rudimentary ones which persist but for a short time). There are from two to five blossoms, usually two, in each bud. The flowers are in umbels, as a rule. The flowers and fruit of cherries are, morphologically, similar to those of plums.

The leading commercial varieties of cherries grown in California have been shown to be self-sterile. It is altogether possible that sterility in cherries is widely spread.

Groups of Cherries.—According to Bailey the principal cultivated cherries are from two species, *Prunus avium*, the sweet cherries, and *Prunus cerasus*, the sour cherries.

PRUNUS AVIUM (Sweet Cherry)

Description.—The sweet cherry is a tall tree, strong-growing, long-lived, and frequently attains a diameter of 1 foot

or more. The bark is gray-brown, the outer layer often being roughened; lenticels are inconspicuous. The *leaves* are thick, oval, ovate or obovate, 4 to 12 centimeters long, abruptly short-acuminate, irregularly and coarsely toothed, or doubly so, green and smooth above, lighter beneath, slightly hairy on the veins, more or less drooping, and with long slender petioles. *Flowers* appear with the leaves, in lateral, sessile umbels; the flower pedicels are 3 to 6 centimeters long; the petals are white, and the stamens 35 or 36. Self-sterility has been reported in the sweet cherry orchards of the Northwest. The *fruit* is variously colored, spherical to heart-shaped, with flesh soft or hard, usually sweet, and with the skin adherent to the flesh.

Geographical.—The species is a native of Europe. It has been cultivated in this country for many years, and in some places has escaped from cultivation.

FIG. 171.—Twig of sweet cherry (Prunus avium). (*After Paddock and Whipple.*)

Groups of Sweet Cherries.—The sweet cherries include four general groups:

1. *Mazzards.*—The fruit is small, and varies in shape and color. Mahaleb and mazzard stocks are the two common sorts upon which sweet cherries are grafted, the results being somewhat better when grown on mazzard stock. Sour cherries are also propagated on mazzard stock.

2. *Hearts* (Geans).—The fruit is heart-shaped and has a soft flesh. Tartarian, Black Eagle, etc., are varieties in this group.

3. *Bigarreaus.*—The fruit is heart-shaped, light or dark in color, and with hard flesh. Common black varieties are

Windsor and Schmidt, common light ones, Yellow Spanish and Napoleon.

4. *Dukes.*—Dukes resemble the Hearts in shape and color, but have a juice somewhat acid. Dukes are often classed with the sour cherries, but Bailey would class them with the sweet cherries on account of the habit of growth of the trees, and the flower and leaf characters. Hedrick considers Duke cherries as hybrids between *Prunus avium* and *P. cerasus*. They resemble sweets more than sour. Dukes commonly produce sterile seed. There are both dark- and light-colored sorts. Reine Hortense and May Duke belong here.

PRUNUS CERASUS (Sour Cherry)

Description.—Sour cherry trees are smaller than those of sweet cherries. They "sucker" readily from the root. The bark is gray-brown and quite smooth; lenticels are conspicuous. The *leaves* are thick, ovate or ovate-lanceolate, abruptly acute or acuminate at the tip, variously toothed, becoming smooth on both surfaces, usually erect, and with short, strong petioles. *Flowers* appear before or with the leaves in small umbels from lateral buds; the pedicels are about 24 centimeters long; and the stamens are about 30 in number. The *fruit* is globular, always red, with soft flesh and skin that usually separates readily from pulp.

Geographical.—The species is a native of Europe and an occasional escape from cultivation in this country.

Groups of Sour Cherries.—The sour cherries include two general groups:

1. *Amarelles.*—These cherries are pale red in color, have colorless juice, and are generally somewhat flattened on the ends. They have less acid than dark-colored cherries. Montmorency and Early Richmond are the most common Amarelles.

2. *Morellos or Griottes.*—These are cherries with dark red fruit and dark juice, and they vary from spherical to heart-shape. Common varieties are Ostheim, Olivet, Louis Philippe, and the Morello.

Other Species of Cherries.—The species of cherries native to America are of little horticultural importance. Chief of these are *P. pennsylvanica*, *P. emarginata*, *P. pumila*, *P. cuneata*, and *P. besseyi*. *P. pennsylvanica* is sometimes used as a stock on which to bud the sour cherry.

Prunus mahaleb, a native of Europe and Asia, is very extensively used in this country as a stock for all sweet and sour cherries. It is an excellent dwarfing stock.

Uses.—Both sour and sweet cherries are used as a dessert fruit, and in the making of pies. The bulk of the cherries grown for canning purposes are sour red sorts, and are produced in New York, Michigan, Wisconsin, and California. Maraschinos are sweet cherries, most of which are imported from Italy and Spain. A Californian variety, Napoleon, is also used to some extent for this purpose. Recent investigations point to the conclusion that a number of commercial products may be obtained from cherry pits and cherry juice, two by-products of the cherry industry. The fixed oil expressed from the fresh kernels is much like almond oil, and can be utilized in similar ways. Also, the volatile oil is quite similar to bitter-almond oil, and can be used in the same way. The pressed cake, that which remains after the oils are removed, may be ground into a meal and used as a feeding stuff. The waste cherry juice can be changed into syrup, jelly and alcohol.

APRICOTS

Stems.—The common apricot varieties belong to the species *Prunus armeniaca*. The trees are small, round-topped, and resemble the peach tree. As in the plums, true terminal buds are seldom formed. Lateral branch buds and flower buds are found together in the axils of leaves (Fig.

172). Except for a few rudimentary leaves, the fruit buds bear only flowers. Normally, there is but one flower (sometimes two) in a bud; they appear before the leaves. The flower buds, which are lateral, occur singly at nodes; often three buds are developed in the axil of a leaf, the central one being a branch bud, while the two laterals are flower buds. However, not all branch buds on a twig are accompanied by flower buds. The vigor of the tree and twigs, and pruning methods will determine the position of the latter, to some extent. In strong-growing twigs, the flower buds are rather near the tip of a year's growth; on twigs of moderate growth, they will be found along the central portion of the twig; while on feeble-growing branches, they usually occur singly, and are quite evenly distributed along the entire length. However, not all the flower buds are formed on the long shoots. Many are developed on extremely short spurs, but always axillary; usually the flower buds are single in such short growths.

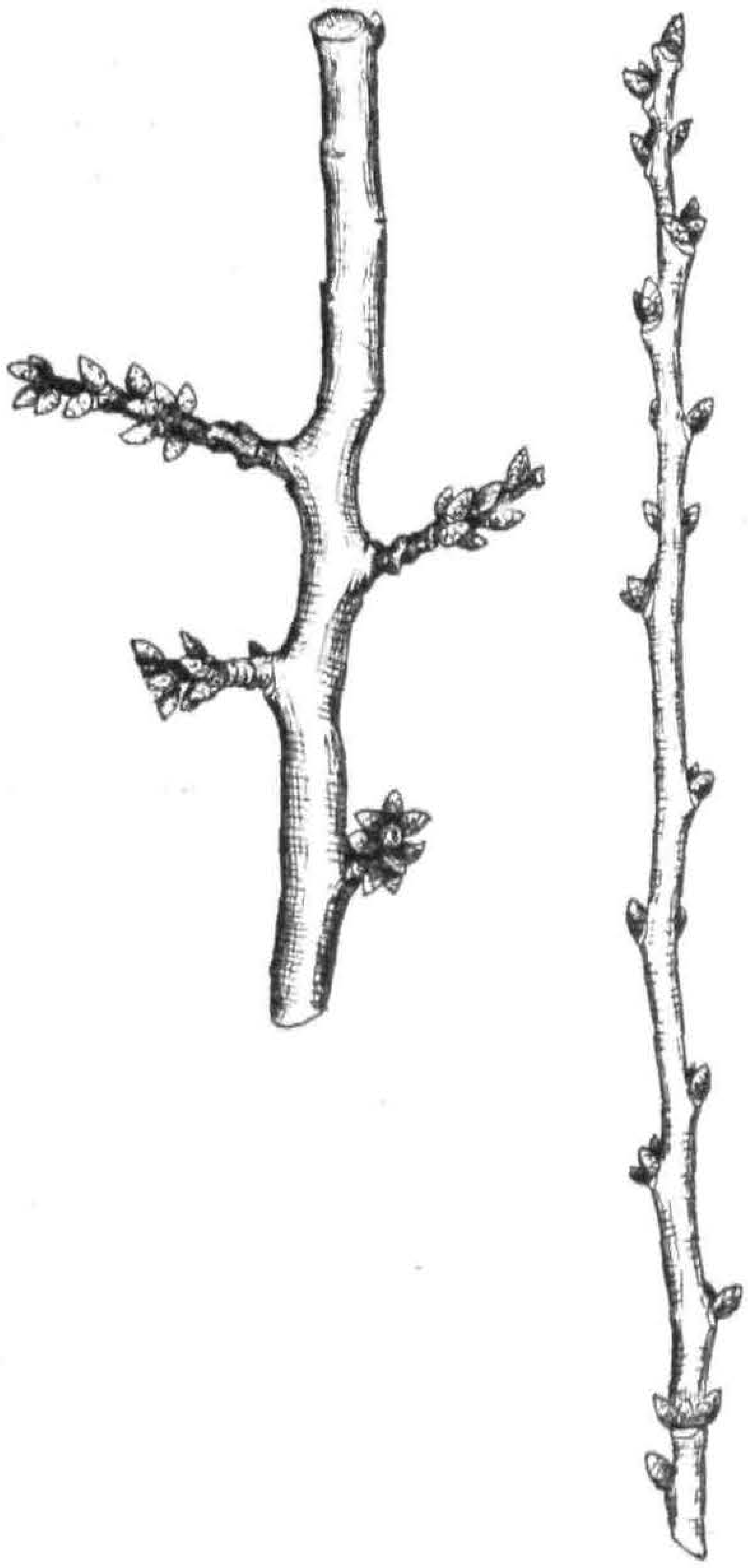


FIG. 172.—Twigs of apricot (Prunus armeniaca). (*After Paddock and Whipple.*)

Leaves.—These are usually ovate, often somewhat heart-shaped at the base, abruptly short-acuminate, smooth

above, slightly hairy beneath, finely toothed, on glandular petioles, and convolute in vernation.

Inflorescence and Flowers.—The flowers are solitary or in pairs, pinkish, sessile or nearly so. Morphologically, the flowers are similar to those of plum, cherry and other *Prunus* species.

Fruit.—This is much like a peach in color and shape; the skin is velvety at first, but becomes smooth at maturity; the flesh is always yellow. The stone (endocarp and seed) is flat, smooth, and grooved on one edge. In the maturing of the fruit, the parts of the flower are cut off by a basal ring of growth, as described in the plums.

Distribution.—The species is considered to be a native of southern Asia. It is now cultivated in most temperate climates. In the United States, the practice is to bud graft apricots on to seedling apricots although seedings of plum and peach are also used as stock. It is regarded that seedling apricot is the best all-round stock.

Other Species.—There are several other species of apricots besides *P. armeniaca*, but none of them bear fruit of marketable size. They are generally planted as ornamentals. Among such are *P. sibirica*, the Siberian apricot, *P. dasycarpa*, the purple or black apricot, and *P. mume*, the Japanese apricot.

Uses.—Apricots are prized as a table fruit, both in the fresh and the dried condition. They are usually pitted before they are dried, but may be dried with the skins off or on. "Sulphuring" may precede the drying process proper. Almond oil is derived from the seeds.

PEACHES

The common varieties of peaches come from one species—*Prunus persica*. Some writers place the peach in a separate genus, *Amygdalus persica*. The latter is the name given to the peach by Linnaeus.

Stems.—The tree is low, seldom over 25 feet in height, broad-topped, and with a scaly, dark brown bark. Young twigs are glossy green. The *flower buds* of the peach are

simple, containing only flowers, or flowers and a few rudimentary leaves; each bud has one, sometimes two, flowers. The flower buds are borne singly or in pairs with a branch bud (Fig. 173). In this respect, they are similar to the apricot.

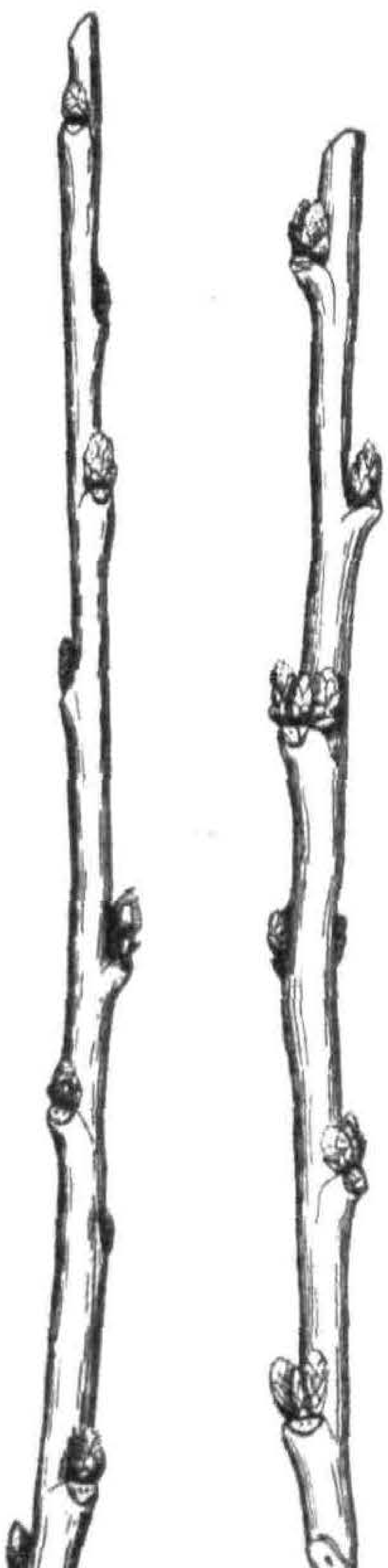


FIG. 173.—Twigs of peach (Prunus persica). (*After Paddock and Whipple.*)

Leaves.—These are conduplicate (Fig. 107) in the bud, elliptic to lanceolate or oblong and taper toward each end; they are finely and sharply toothed, and on stout petioles.

Inflorescence and Flowers.—The flowers are normally solitary in the axils of leaves and appear before the leaves; they are large, pink, fragrant, and showy.

Fruit.—The fruit is subglobular, grooved slightly on one side, has velvety skin, and hard flesh which may be free (freestones) or adherent (clingstones) to the stone. The stone is compressed, pointed, and pitted. The seed is of the shape of an almond, aromatic, and slightly bitter.

History and Geographical Distribution. The original home of the peach is China, and at the present time, wild peaches are found growing in many parts of that country. There is historical evidence that the peach was cultivated in China many hundreds of years before its introduction into the countries of sanskrit-speaking peoples, and into the Greco-Roman world. The peach was probably introduced into Europe in the third or fourth century B. C.; the first mention of it in ancient Greece is found in the writing of Theophrastus

(322 B. C.) who speaks of it as a fruit of Persia; hence the specific name *persica*, and common name, peach.

There is evidence for the belief that "in the native peaches of China may be found all of the characters that distinguish cultivated peaches wheresoever found;" and "that none of the prominent characters of peaches have originated within the period covered by history—all exist in China and probably have so existed since time beyond record." (Hedrick.)

The peach today is one of the leading fruits in Japan, and is as commonly grown in the countries of western Asia as of eastern Asia. It has been said that "next to the pomegranate, the Asiatics prize the peach."

Following its introduction into Greece, probably during the third or fourth century B. C., the peach spread through southern European countries, and from Pliny's writings, among which are described six varieties of peaches, it may be concluded that this tree was commonly grown in Italy at the beginning of the Christian era. The peach has been found in France since very early times, and it is known that from French nurseries, the other countries of western Europe and England obtained their stock. The peach was introduced into America (Mexico) by the early Spanish conquerors. From these early introductions, the plant spread through out the southern part of the United States, where the naturalized forms have long gone by the name of "Indian Peach."

The cultivation of the peach in the United States has gradually extended, until today, it is one of our staple fruits, and is represented here by over 1,000 sorts.

Types of Peaches.—The first system of classification of peaches was worked out by Onderdonk. He divides the varieties of peaches into five classes or races, based primarily upon the country in which they originated, hence upon their range of adaptability.

1. *Peen-to Race.*—The stone is almost spherical (Fig. 174, C, D), somewhat compressed at the end, and with small and round corrugations; the fruit (of original peen-to) is much flattened; the skin is white, blotched with red, and flesh white; the stone is free or cling. It is adapted to subtropical regions. Varieties: Angel, Clara, Hall, Waldo.

2. *South China Race* ("Honey" Group).—The stone is oval (Fig. 174, B), and its corrugations slight; the fruit is

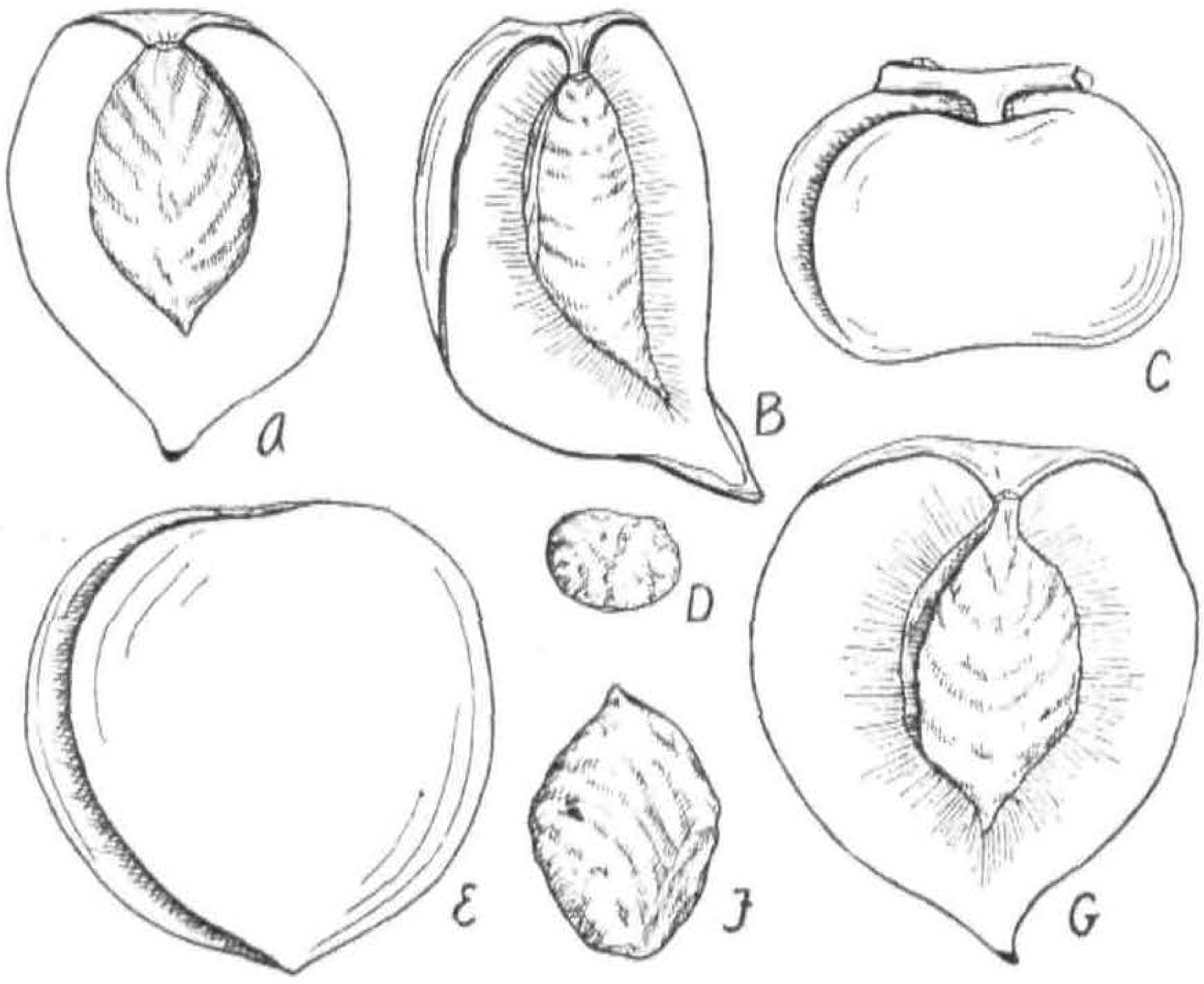


FIG. 174.—Fruit of the races of peaches. *A*, Spanish Race; *B*, South Chinese Race; *C*, Peen-to Race; *D*, stone of Peen-to Race; *E*, Persian Race; *F*, stone of Persian Race; *G*, North Chinese Race. (*After Price, Texas Agr. Exp. Sta.*)

slightly flattened, with a peculiar long, conical apex more or less recurved, small, oval, and has a very deep suture at the stem end; the flesh is juicy, firm, generally white; the stone is free or cling. It is adapted to subtropical conditions. Varieties: Climax, Imperial, Pallas, Taber.

3. *Spanish Race.*—The stone is large, oval, nearly flat (Fig. 174, A), its apex prominent, and corrugations small; the fruit is large, yellow, or yellow streaked with red. It is adapted to southern conditions. Varieties: Cabler, Druid, Onderdonk, Texas.

4. *North China Race* ("Chinese Clings").—The stone (Fig. 174, G) is globular, thick, its corrugations not at all prominent, cling, semi-cling or free; the fruit is large, almost globular, and its flesh is fine-grained and juicy. It has a wide range of adaptability. Varieties: Belle, Lee Ray, Superb. Elberta and several other varieties are considered crosses between the North China and Persian races.

5. *Persian Race.*—The seed is globular, with corrugations prominent toward the apex (Fig. 174, E, F); the fruit is much like the preceding. The common varieties of peaches grown in northern orchards belong to this race. Varieties: Crothers, Foster, Late Crawford, Reeves, Salway, Walker.

In addition to the above, the *Nectarine* should be mentioned as a variety of peach. It differs from the common peach in that its fruit is smaller, the skin is smoother, the flesh firmer and the leaves are commonly more prominently toothed. There are both freestone and clingstone nectarines. It is known that nectarines appear on peach trees and peaches on nectarine trees. Such fruits that thus appear are bud variations. The nectarine can be grown wherever the peach thrives; however, it attains its greatest perfection in this country in the states west of the Rocky mountains, particularly in California where it is extensively cured and canned.

Uses, and Production of Peaches in the United States.—The fruit is used largely as a dessert, both fresh, dried and canned. Peaches are usually pitted before they are dried. The seeds of the peach, as well as those of almond, apricot and plum, contain both fixed and volatile oils, which are of commercial value.

There are peach interests of commercial importance in a large proportion of the States. The commercial value of all other stone fruits does not exceed that of the peach. The total output of peaches for the country in 1915 was 64,218,000 bushels. California led in production, with 9,768,000

bushels. The other nine leading States, in the order of their output, were Arkansas, Georgia, Texas, Missouri, Alabama, Kansas, Tennessee, Oklahoma and Ohio.

ALMONDS

Description.—The common almond is *Prunus amygdalus* (*Amygdalus communis*). The tree is much like the peach in shape and size, but the wood is harder and the tree is longer lived. The *flower buds* are axillary along with branch buds, as in the peach and apricot. The *leaves* are lanceolate, firm, shining, and finely toothed. The *flowers* are normally solitary and appear before the leaves. They are large, pink, and showy. In almonds the chief pollinating agency is the honey bee, and on this account it is recommended that honey bees be provided for the orchard.

Many varieties of almonds are self-sterile, and some varieties are practically intersterile. Experiments have determined in many instances which varieties are interfertile, that is which varieties when grown together will give the highest percentage of fertile blossoms. The *drupe* is much compressed. The mesocarp (portion corresponding to the flesh of peach or plum) is leathery and tough and separates readily at maturity from the stone (endocarp and seed). The "unshelled" almond of commerce consists of the thin, pitted, light-colored endocarp, within which is the seed or "kernel."

The common almond is a native of Asia.

Types of Almonds.—The two general types or races of common almonds are the *bitter* and the *sweet*. The difference is in the composition and taste of the kernel. The sweet or edible almonds consist of two groups: *Hard-shell* and *soft-shell*. The latter are of the greater economic importance.

In addition to the common almonds, *Prunus amygdalus*, there are a number of dwarf forms which are grown mostly as ornamentals.

Uses.—Sweet almonds are grown for the nuts which are used directly as a food. Bitter almonds are employed largely in the manufacture of *almond oil* which finds use in the manufacture of flavoring extracts; the seeds are also a source of prussic acid. The bitter almond is also used in nurseries as a root stock upon which to bud the sweet almond and certain other fruits.

Almond Oil.—Most of the so-called oil of almonds is derived from the seeds of the apricot; almond and peach seeds also furnish a considerable quantity. The oils from these three sources are very nearly the same. In the process of extracting almond oil, the seeds are ground, subjected to great hydraulic pressure to remove the undesirable fatty oil, and the residue ground again, fermented, and distilled with steam. The distillate is almond oil and hydrocyanic acid. This latter, deadly poisonous substance is removed by treating the mixture with lime and copperas.

References

BAILEY, L. H.: Fourth Report on Japanese Plums. Cornell Exp. Sta. Bull. 175: 131–160, 1899.

BAILEY, L. H., and POWELL, G. H.: Cherries. Cornell Agr. Exp. Sta. Bull. 98: 471–500, 1895.

EARLE, F. S.: Japanese Plums. Ala. Agr. Exp. Sta. Bull. 85: 423–448, 1897.

GARDNER, V. R.: A Preliminary Report on the Pollination of the Sweet Cherry. Ore. Agr. Exp. Sta. Bull. 116: 1–40, 1913.

GOETHE, R.: Über die Klassification der Pfirsichsorten. Gartenflora, 55: 169–182, 1907.

GOULD, H. P.: Growing Peaches: Varieties and Classification. U. S. Dept. Agr. Farmers' Bull. 633: 1–18, 1914.

HEDRICK, V. P.: The Cherries of New York. 22d Ann. Rept. N. Y. Agr. Exp. Sta., vol. 2, part 2: 1–371, 1915.

The Peaches of New York. 24th Ann. Rept. N. Y. Agr. Exp. Sta., vol. 2, part 2: 1–541, 1917.

The Plums of New York. 18th Ann. Rept. N. Y. Agr. Exp. Sta., vol. 3, part 2: 1–616, 1911.

The Blooming Season of Hardy Fruits. N. Y. Agr. Exp. Sta. Bull. 407: 367–391, 1915.

HENDRICKSON, A. H.: The Common Honey Bee as an Agent in Prune Pollination. Calif. Agr. Exp. Sta. Bull. 174: 127–132, 1916.

HUME, HAROLD H.: The Peen-to Peach Group. Fla. Agr. Exp. Sta. Bull. 62: 505–519, 1902.

ONDERDONK, GILBERT: Report of the Commissioner of Agr., 1887, pp. 648–650. Containing the Original Classification of the American Varieties of Peaches.

POWELL, G. HAROLD: The Chinese Cling Group of Peaches. Del. Agr. Exp. Sta. Bull. 54: 1–32, 1902.

PRICE, R. H.: The Peach. Tex. Agr. Exp. Sta. Bull. 39: 803–848, 1896.

QUAINTANCE, A. L.: The Development of the Fruit Buds of the Peach. Ga. Exp. Sta. Rept. 13: 349–351, 1900.

RABAK, FRANK: Peach, Apricot, and Prune Kernels as By-products of the Fruit Industry of the United States. U. S. Dept., Bur. Plant Indus. Bull. 133: 1–34, 1908.

The Utilization of Cherry By-products. U. S. Dept., Bur. Plant Indus. Bull. 350: 1–24, 1916.

REIMER, F. C.: The Honey Peach Group. Fla. Agr. Exp. Sta. Bull. 73: 135–153, 1904.

TUFTS, W. P., and PHILP, G. L.: Almond Pollination. Calif. Agr. Exp. Sta. Bull. 346: 1–35, 1922.

WIGHT, W. F.: Systematic Botany of the Plum as Related to the Breeding of New Varieties. Ann. Rept. Am. Breeders' Assn., 8: 488–497, 1912.

The Varieties of Plums Derived from Native American Species. U. S. Dept. Agr. Bull. 172: 1–44, 1915.

Native American Species of *Prunus*. U. S. Dept. Agr. Bull. 179: 1–75, 1915.

CHAPTER XXIX

LEGUMINOSÆ (Pea Family)

The pea family is one of wide geographical distribution, occurring both in temperate and warm climates. According to Piper there are about 487 genera and 10,782 species in the family. Of these, 3,846 species in 103 genera are American.

"*Legume*" is a popular name applied to members of the Leguminosæ. Probably no family is of greater agricultural importance than this one, unless it is the Gramineæ. Leguminous plants are comparatively rich in protein; this applies to all portions of the plant, and not to seeds alone. For this reason they help to balance the food ration of man and of domestic animals, which is quite largely made up of starchy foods, such as are furnished by the cereal crops. Furthermore, the fact that legumes are rich in nitrogenous substances makes them of value as fertilizer crops. Moreover, they leave a considerable quantity of vegetation behind them when harvested, and thus add humus to the soil, which improves both the chemical and physical properties of the soil.

Root Tubercles.—The roots of the legumes support the growth of a bacterium (*Pseudomonas radicicola*) which forms upon them abnormal growths called nodules or tubercles. The tubercles are root colonies of the above organism, which stimulates rapid growth of certain root cells and hence the formation of swollen, gall-like structures. These organisms have the power of fixing free nitrogen of the air. That is, free nitrogen gas from the soil air is taken by the organism

and, together with other chemical elements, made a part of its protein. It is probable that the legume bacteria, while active in the nodule, are throwing off continuously nitrogenous substances which are absorbed directly by the plant upon which they are growing. Moreover, when the nodules decompose, their protein contents are ammonified, and nitrified, and finally there is left in the soil, nitrates which are available as a source of nitrogen for green plants. Legumes are regularly employed as rotation crops with cereals, and root crops. Since they are heavy soil feeders, they make excellent crops to plow under.

Duration and Form.—Leguminosæ are either annual, biennial or perennial; and are either herbs (peas, beans, alfalfa, etc.), shrubs (*Genista*, dye-weed or green-weed), or trees (*Robinia* and *Gleditsia*, locusts), and a very few are vines (*Vicia* spp., vetches).

Leaves.—These are alternate on the stems, stipulate, and mostly compound. They are generally odd-pinnate, that is, a leaflet terminates the rachis of the leaf, as in *Robinia* (locust), *Astragalus* (vetches) and *Aragallus* (loco); sometimes they are even-pinnate, that is, terminated by a tendril or bristle, as in *Vicia* (vetch) and *Lathyrus* (wild and sweet peas); or they may be trifoliate, as in clovers, or digitate, as in *Thermopsis* (buckbean).

Inflorescence.—The flowers are nearly always arranged in racemes (pea), sometimes in a head (clovers), or spike-like raceme (alfalfa), or spike (*Glycyrrhiza*, licorice).

Flowers.—These are irregular (Fig. 175); they have a butterfly-like shape, and for this reason, flowers of the pea type are often spoken of as "papilionaceous." The *calyx* in normally four- to five-toothed or cleft, the teeth or lobes being equal or unequal. The *petals* are usually five in number, a broad upper one (*standard*, *banner* or *vexillum*), two lateral ones (*wings* or *alæ*), and two lower ones more or

less united along their ventral edges (forming the *keel* or *carina*) (Fig. 175); this keel encloses the stamens and pistils. In the bud, the keel is enclosed by the wings, and the wings by the standard. *Stamens* are mostly ten in number, and either all the filaments are united (*monadelphous*), as in *Lupinus*, or nine are united and one is free (Fig. 188) (diadelphous), as in clovers and alfalfa, or rarely all stamens are separate (polydelphous), as in *Sophora* and *Thermopsis*. The united stamens form a tube enclosing the pistil in monadelphous and diadelphous forms. There is a single

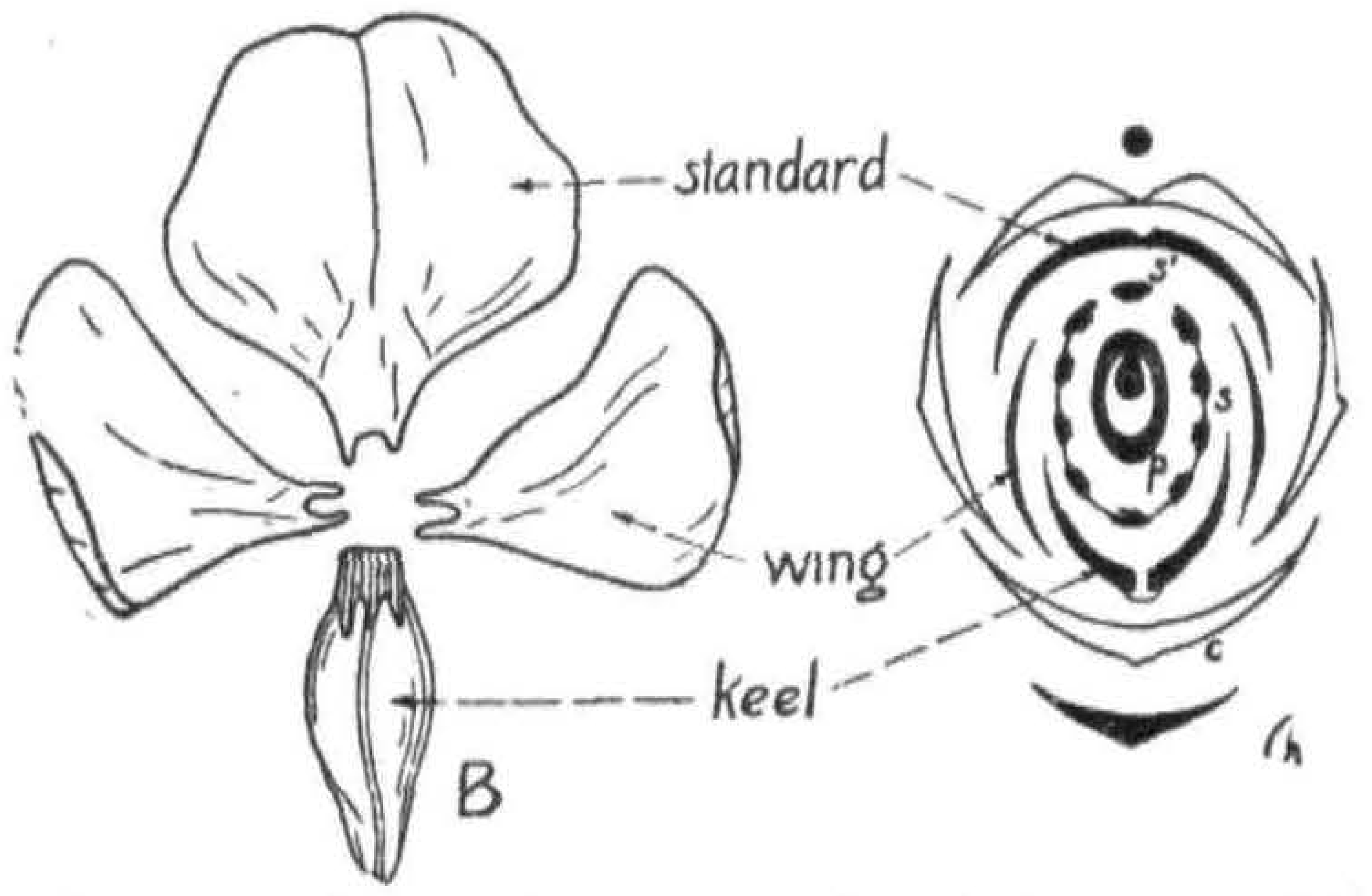


FIG. 175.—Flower of Leguminosæ. *A*, floral diagram of Vicia faba; *B*, sweet pea flower, dissected, diagrammatic. (*A after Eichler, B after Bergen and Caldwell.*)

superior pistil; the *ovary* is usually one-celled, sometimes two-celled by the intrusion of the sutures, as in some *Astragalus* spp., or occasionally several-celled by cross-partitions; there is one style, and one to many ovules.

Fruit.—In nearly all members of the family, the fruit is a legume or pod, that is, a fruit of one carpel which opens along two, both the ventral and dorsal, sutures. The ventral suture of the bean or pea pod, for example, is the one along which the seeds are attached. In one tribe (Hedysareæ), the fruit is a loment, that is, a jointed indehiscent legume, constricted between the seeds. The style, calyx, and withered stamens are often partly persistent in the fruit.

Seeds.—The seeds are usually without endosperm; the cotyledons are thick and full of food.

The seeds of legumes are noted for their great longevity. Some have been known to retain their viability for 150 to 250 years. This is correlated with their very hard, impermeable seed coats. So-called "hard seeds" are very common in the pea family. Such seeds are tardy in their germination, either under laboratory or field conditions. As a rule, only a portion of a crop of seeds is hard, although in some cases the whole crop may be hard. It is claimed that a larger percentage of hard seeds is produced in dry climates or when ripening takes place under dry seasonal conditions than in moist climates or moist seasons. The permeability of leguminous seeds can be increased by "scarifying," that is, passing them through a machine that abrases the surfaces. The ordinary alfalfa huller is effective as an abraser, as is shown by the experiments of Harrington who found that alfalfa seed, grown under a variety of soil and climatic conditions, had about 90 per cent. of hard seeds if hulled by hand and only about 20 per cent. if hulled by machine.

Key to Principal Genera of Leguminosæ

Plants with tendril-bearing leaves (Fig. 20).
  Calyx lobes leafy; stipules large, rounded (Fig. 20), *Pisum* (pea).
  Calyx lobes not leafy; stipules mostly small, pointed.
    Style slender, bearded at the tip (Fig. 176, A), *Vicia* (vetch).
    Style flattened, bearded along the inner side (Fig. 176, B), *Lathyrus* (vetchling).
Plants without tendril-bearing leaves.
  Leaves palmately three-foliate (Fig. 183), *Trifolium* (clover).
  Leaves pinnately three-foliate, rarely five- to seven-foliate (Fig. 182).
    Flowers small, many in a cluster.
      Flowers in slender, spike-like racemes, *Melilotus* (sweet clover).
      Flowers in heads or short spikes, *Medicago* (alfalfa and other medicks).
    Flowers medium to large, few in a cluster.
      Pods smooth.

Keel of corolla spirally coiled (Fig. 177, A), *Phaseolus* (bean).
Keel of corolla merely incurved, *Vigna* (cowpea).
Pods hairy.
Twining plants, *Stizolobium* (velvet bean).
Erect or spreading, not twining, *Soja* (soy bean).
Leaves pinnate, with two pairs of leaflets, *Arachis* (peanut).

PISUM (Pea)

Description.—The plants are herbaceous trailers or climbers with hollow *stems*. The *leaves* are pinnately compound, with one to three pairs of leaflets, the terminal one, and in some cases the upper lateral ones, modified as tendrils, which are sensitive and prehensile; the stipules are large and leaf-like (Fig. 20). The *inflorescence* is a few-flowered axillary raceme. The *flowers* are either white or purplish, diadelphous, and bear a single pistil with the style bearded on the inner side (Fig. 176, A). The pea is capable of self-fertilization although it may sometimes be cróss-fertilized. The mature *fruit* is a typical legume with a number of smooth or wrinkled, usually green or yellow seeds ("peas"). Gregory studied the histology of round and wrinkled peas. In round peas, including the indented sugar peas, the central tissue in the cotyledon leaves is filled with very large starch grains. In wrinkled peas, on the other hand, this region of the cotyledons has starch grains which are usually compound, the component parts being about one-half the size of the grains in smooth peas. The seed coat is thin; endosperm is wanting; the stored food is within the two cotyledons. The cotyledons remain underground during germination (*hypogean* germination), as in all cereals. This type of germination is different

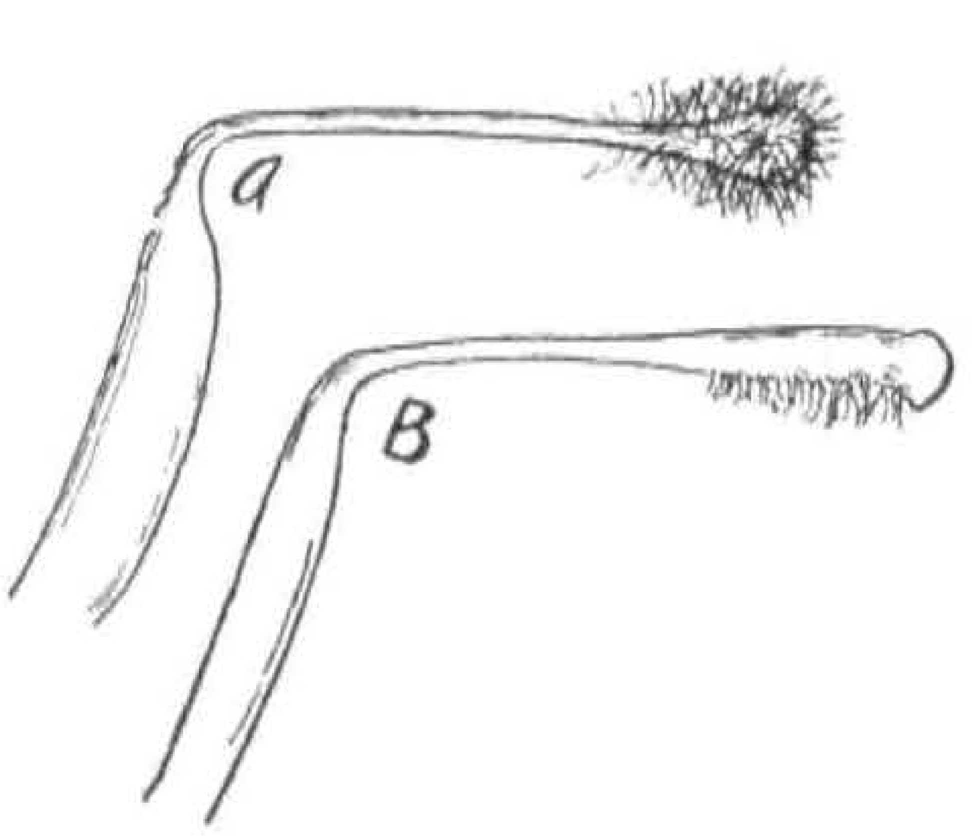


FIG. 176.—*A*, style and stigma of Vicia; *B*, same of Lathryus.

from that in the bean and squash, for example, in which the two cotyledons are raised above ground, and for a time are food-making organs. This sort of germination is called *epigean*.

Types of Peas.—There are but two well-recognized types of *Pisum: Garden peas* and *field peas*. These are briefly distinguished as follows:

Flowers white; seeds globular, uniformly yellowish, white or bluish green; leaf axils green, unpigmented; comparatively tender, *Pisum sativum* (garden pea).

Flowers colored, usually purplish, red or lavender; seeds angular, gray-brown, gray-green, gray-yellow or gray speckled with fine spots of various colors; leaf axils pigmented; comparatively hardy, *Pisum sativum* (field pea).

Garden Peas.—The common garden pea can be divided into two groups: *Shelling peas*, and *edible-podded* or *sugar peas*. In the former, the pod is lined on the inside by a thin, hard membrane (endocarp) which at maturity causes it to split open. In the edible-podded or sugar peas, this membrane does not become dry and twisted at maturity, and the pods remain soft and tender.

Shelling Peas.—Vilmorin classifies the varieties of common shelling peas into two groups: *Round* or *smooth-seeded*, and *wrinkled-seeded*. Each of these is divided into (1) *tall climbing*, (2) *half-dwarf*, and (3) *dwarf* varieties, and each of the latter three groups into *white-seeded* and *green-seeded* sorts. The sugar peas occur in both tall, half-dwarf, and dwarf forms.

Period of Maturing.—As a general rule, the earliest sorts of peas have smooth, round seeds, while the late sorts have wrinkled seeds. Smooth-seeded varieties are hardier than wrinkled-seed varieties. This is not invariably the case, however. Furthermore, dwarf and medium-sized forms are early, while tall varieties are late. Green garden peas are sometimes classified as to their time of maturing into

early, *medium*, and *late* or *main* crop. Well-known early varieties are Alaska, Thomas Laxton and Gradus; medium maturing varieties, Senator and Lincoln; and late maturing varieties, Telephone, Carter's Daisy, and Stratagem.

Field or Canadian Field Peas.—These have smooth, hard, rather angular seeds. They are gray-green, gray-yellowish, or gray dotted with purple, blue, rust red or brownish spots. Garden peas are sometimes used as a field crop.

Field peas are successfully grown only in those regions with a cool growing season, in fact, they will withstand quite heavy frosts. High temperatures accompanied by high relative humidity are decidedly injurious. Excellent crops are grown at 7,000 to 8,000 feet in the San Luis Valley of Colorado. They do well on most types of soil.

Peas and Mendelism.—Gregor Mendel's famous experiments in plant hybridization were carried on with the common garden pea. He discovered certain laws in the behavior of his hybrids, and these are now famed as *Mendel's Laws.* He selected a number of differentiating (paired) characters and observed their behavior when crossed with each other. In the brief summary, here of his work, a number of characters of the genus Pisum are brought out:

1. Round or roundish form of seed is dominant over angular or wrinkled seed. That is, when a plant bearing roundish seeds is crossed with one bearing angular or wrinkled seeds, the hybrid offspring bears seeds all of which are roundish.
2. Yellow color of cotyledons is dominant over green color of cotyledons.
3. Gray seed coats are dominant over white seed coats.
4. Inflated seed pods are dominant over pods constricted between the seeds.
5. Green color of unripe pods is dominant over yellow color of unripe pods.
6. Distribution of flowers in leaf axils is dominant over their distribution on the ends of stems.
7. Tall stem is dominant over short stem.

Uses.—Peas in the green state are one of the most common vegetables. They are also canned in large quantities. Field peas are being grown as a companion crop, soiling crop, green manure, and as a food for hogs, sheep, horses and cattle. It is the practice in many places to pasture live stock, particularly hogs and sheep, on field peas.

PHASEOLUS (Bean)

Description.—Representatives of this genus are annual or perennial herbs or vines with pinnately three-foliate, rarely one-foliate, *leaves*. The *flowers* occur in axillary racemes; they vary in color: white, yellow, red, or purple. The *calyx* is five-toothed or five-lobed, the two upper teeth or lobes being either united or free. The standard of the *corolla* is often recurved or somewhat contorted; the wings equal or exceed the standard, while the *keel is characteristically spirally coiled* (Fig. 177, A). The *stamens* are diadelphous (nine and one). The *ovary* has a style longitudinally bearded, and numerous ovules. Members of the genus are quite regularly visited by insects. The *pod* is linear, straight or curved, subterete or compressed, two-valved, and tipped with a persistent style. The *seeds* ("beans") are large and have a prominent, approximately central hilum, on one side of which is the micropyle, on the other, the raphe. The *embryo* is large and occupies the whole of the seed, *i.e.*, endosperm is wanting. The hypocotyl and plumule are prominent; the two large cotyledons are slightly concave on their inner faces.

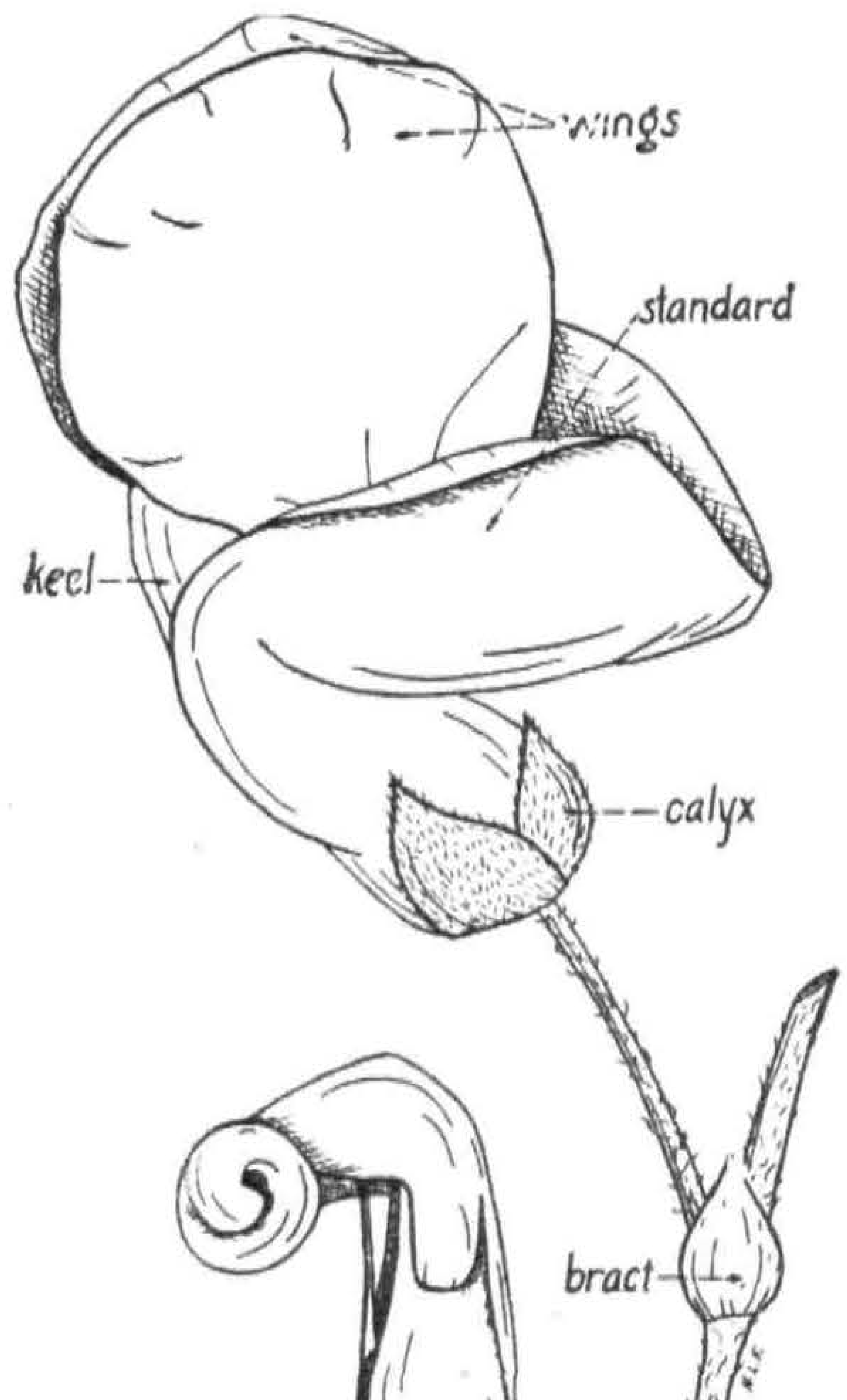


FIG. 177.—Common kidney bean (Phaseolus vulgaris). *A*, spiral keel; *B*, entire flower. × 2½.

Geographical and Species.—Members of the genus *Phaseolus* are tropical and warm-country plants. According to Britton and Brown, there are close to 180 species.

A number of "beans" do not fall within the genus *Phaseolus*, for example, broad bean (*Vicia faba*), soy bean (*Soja max*), velvet bean (*Stizolobium* spp.), asparagus or dolichos bean (*Vigna sesquipedalis*), cowpea or bean (*Vigna sinensis*), Jack bean (*Canavalia ensiformis*), locust bean (*Ceratonia siligna*) and hyacinth bean, bonavist or lablab (*Dolichos lablab*).

The adjuki bean (*Phaseolus angularis*) and mung bean (*Phaseolus aureus*) are now grown to some extent in this country.

KEY TO PRINCIPAL SPECIES OF PHASEOLUS

Roots tuberous or much thickened, *P. multiflorus* (scarlet runner bean).
Roots fibrous.
  Seeds flat or flat-oval in cross-section, with conspicuous lines radiating from the hilum to the dorsal margin, *P. lunatus* (Sieva and Lima beans).
  Seeds mostly circular, but sometimes flat in cross-section, with no conspicuous lines as above, *P. vulgaris* (kidney bean).

PHASEOLUS MULTIFLORUS (Scarlet Runner Bean, Dutch Case-knife Bean, Flowering Bean, or Painted Lady)

These are perennials which usually have tall, climbing *stems* and pinnately trifoliate *leaves*. The large and showy

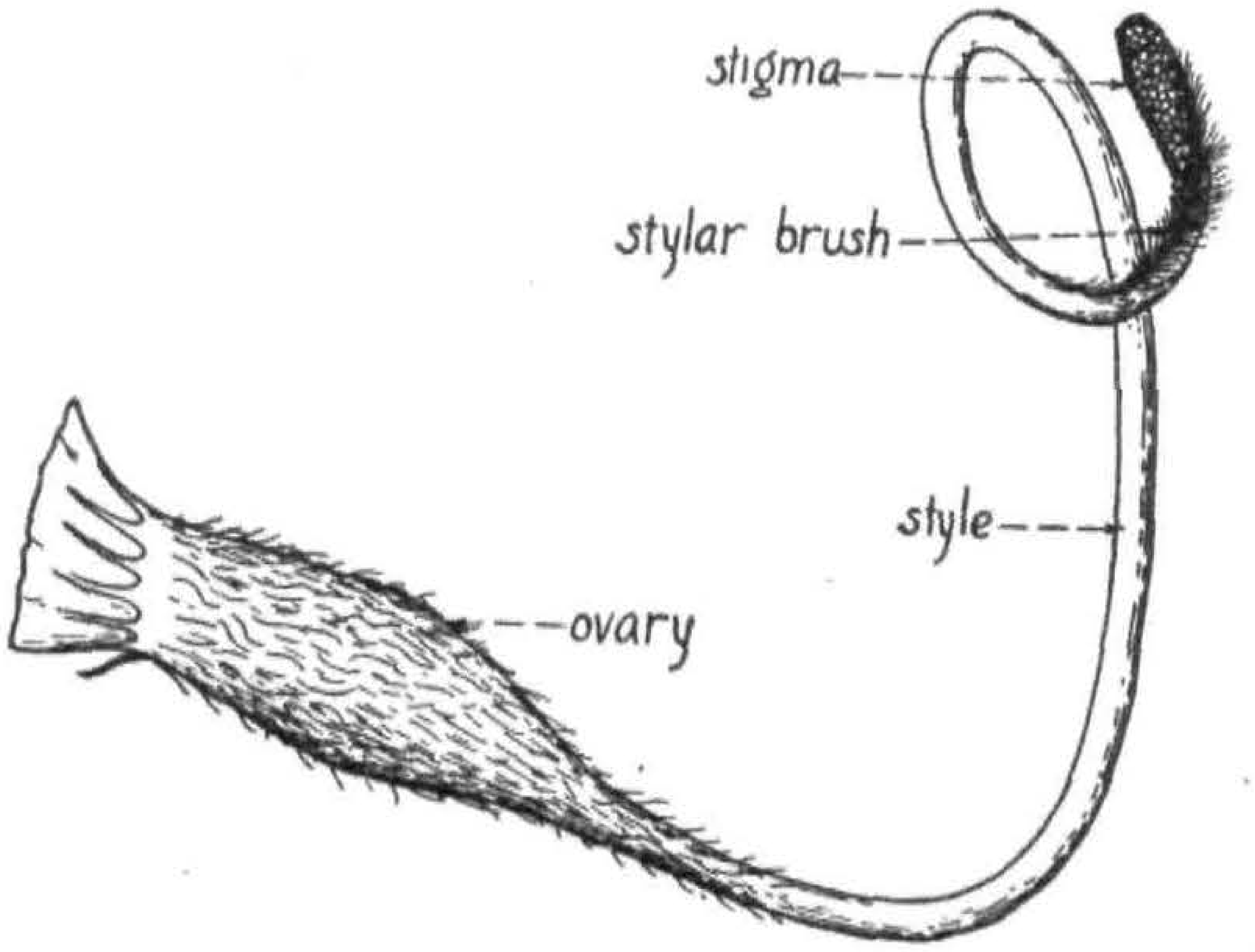


FIG. 178.—Pistil of flower of common bean (Phaseolus vulgaris). (*After Knuth.*)

flowers are scarlet (scarlet runner), or white (Dutch case-knife), and form racemes. *Pods* are 3 to 6 inches long, and

curved; the seeds are large and plump, flattened or cylindric, and vary in color.

The scarlet runner form is also known as the flowering bean or painted lady, and is much used as an ornamental vine. The Dutch case-knife form of this species—one with white flowers—is grown for the edible beans. The Aroostook bush Lima bean is considered by Tracy to be a bush form of *Phaseolus multiflorus*. The species is raised to some extent by the Mexicans, and it is very probable that some at least of the so-called "Mexican beans" are varieties of this species.

Phaseolus multiflorus is a native of South America and Mexico.

PHASEOLUS LUNATUS (Sieva and Lima Beans)

These vary in form from low and bushy to tall and climbing. The *leaves* are pinnately trifoliate, the leaflets varying from narrowly lanceolate to ovate. The *flowers* are small, and in axillary racemes. The *pods* are usually broad and flat, and have flattened, variously colored beans.

The native home of these beans is tropical South America. They require higher temperatures than the varieties of *Phaseolus vulgaris*.

Classifications of Types of Lima Beans.—There are two general types of Limas, as follows: (1) *Phaseolus lunatus*, including the Sieva or Carolina type of Lima, and (2) *P. lunatus* var. *macrocarpus*, including the true Limas. The latter have a taller and much more robust growth, and thicker leaflets than the Sievas or Carolinas. In both groups above, there are pole and bush forms.

TABLE SHOWING RELATIONSHIP OF TYPES OF LIMA BEANS

Phaseolus lunatus (Sieva, Civet, or Carolina beans).
  Plants bush (Henderson's Bush Lima).
  Plants pole (Small White Lima, Florida Butter).

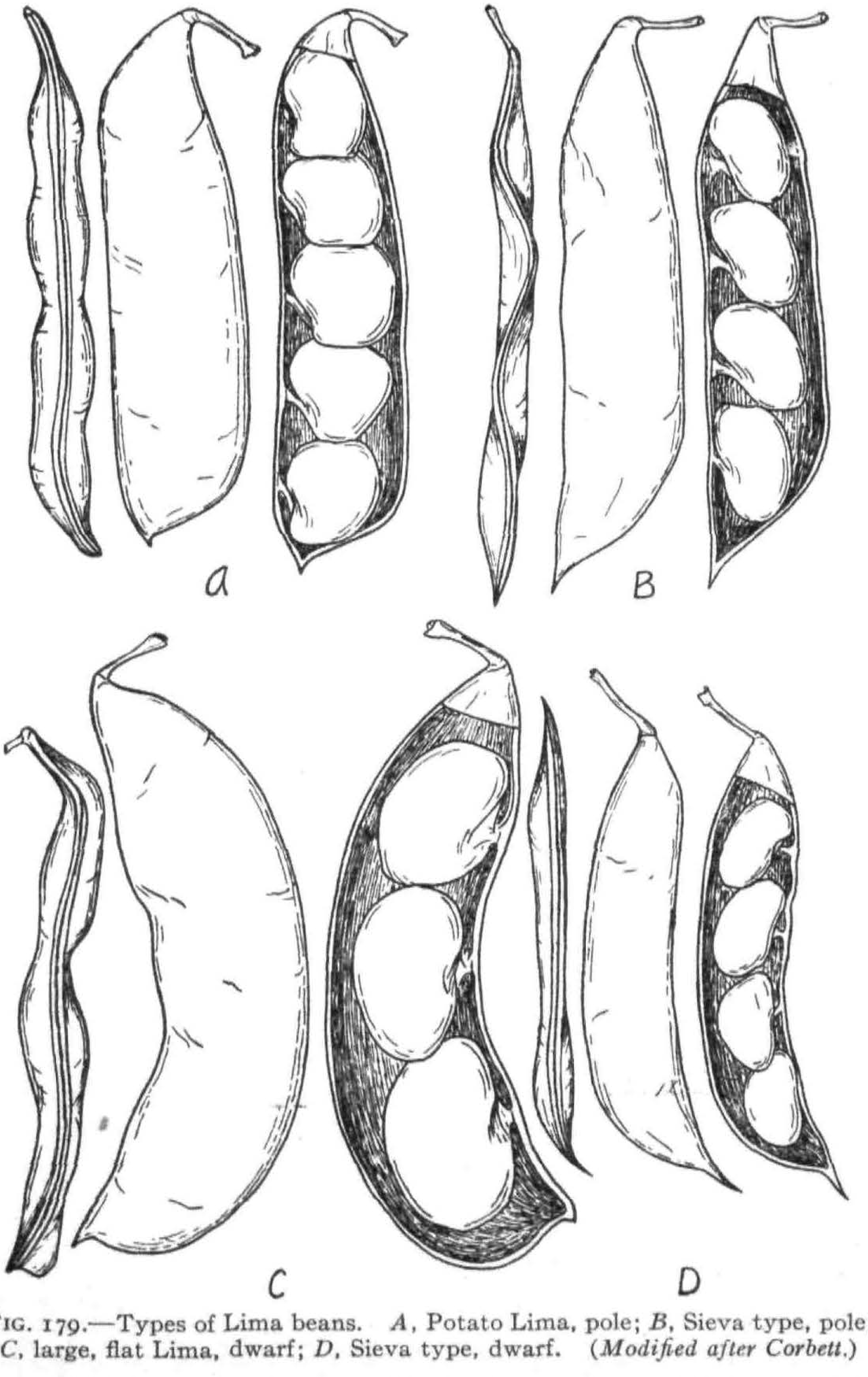


FIG. 179.—Types of Lima beans. *A*, Potato Lima, pole; *B*, Sieva type, pole; *C*, large, flat Lima, dwarf; *D*, Sieva type, dwarf. (*Modified after Corbett.*)

Phaseolus lunatus var. *macrocarpus* (true Limas).
  Seeds very flat and veiny; pods broad and flat, with tip not prominent, leaflets broad, not ovate, *Flat-seeded Limas.*
    Plants bush (Burpee's Dwarf Lima).
    Plants pole (King of the Garden).
  Seeds smaller; pods short and thick, with prominent tip; leaflets tapering, long ovate, *Potato Limas.*
    Plants bush (Dreer's Dwarf Lima).
    Plants pole (Dreer's Improved).

PHASEOLUS VULGARIS (Kidney Bean)

These are annual plants, with pinnately trifoliate *leaves* and ovate leaflets. The *flowers* are small, not over 5/8 inch across the wing, and are white, yellowish, or blue-purple. The slender *pods* vary in shape, and have kidney-shaped seeds.

This species is thought to be a native of tropical America. The cultivated varieties thrive best where the growing season is warm.

There are, according to Tracy, 145 varieties of kidney beans in America. These are usually divided into two large subdivisions, *pole* and *bush.* These in turn each possess green-podded and wax-podded sorts. The bush beans are often grouped together under the variety *P. vulgaris nanus.* Most of our common garden sorts are dwarf or bush beans.[1]

The stringiness of bean pods is due to strips of inedible, tough fibers at the sutures.

Uses of Beans.—Beans are used in large quantities dried, and in the pod as "green beans." Lima beans are often canned with corn in succotash. Great quantities of common kidney beans are put up in the form of "pork and beans." The Mexicans and southwestern Indians raise beans in large amounts; beans constitute one of their chief articles of diet.

[1] For a detailed classification of American varieties of beans see Bull. 109, Bureau of Plant Industry, by W. W. Tracy.

VICIA (Vetch, Broad Bean)

Generic Description.—The *Vicias* are climbing or trailing herbaceous vines. The *leaves* are pinnate, tendril-bearing, and with half-sagittate or entire stipules. The *flowers* are blue, violet, yellowish, or white, and in axillary racemes. The *calyx tube* is oblique, and its teeth or lobes are about equal, or the two upper ones somewhat longer. The standard is notched at the tip, and the wings are attached to the curved keel. The *stamens* are diadelphous (nine, and one) or monadelphous below, and have filiform filaments. The sessile or stipitate *ovary* has numerous ovules and a slender style with a tuft or ring of hairs at its summit (Fig. 176, A). The *pod* is flat.

Geographical.—There are more than 100 species of *Vicia*, of wide geographical distribution. There are about 20 wild species in the United States.

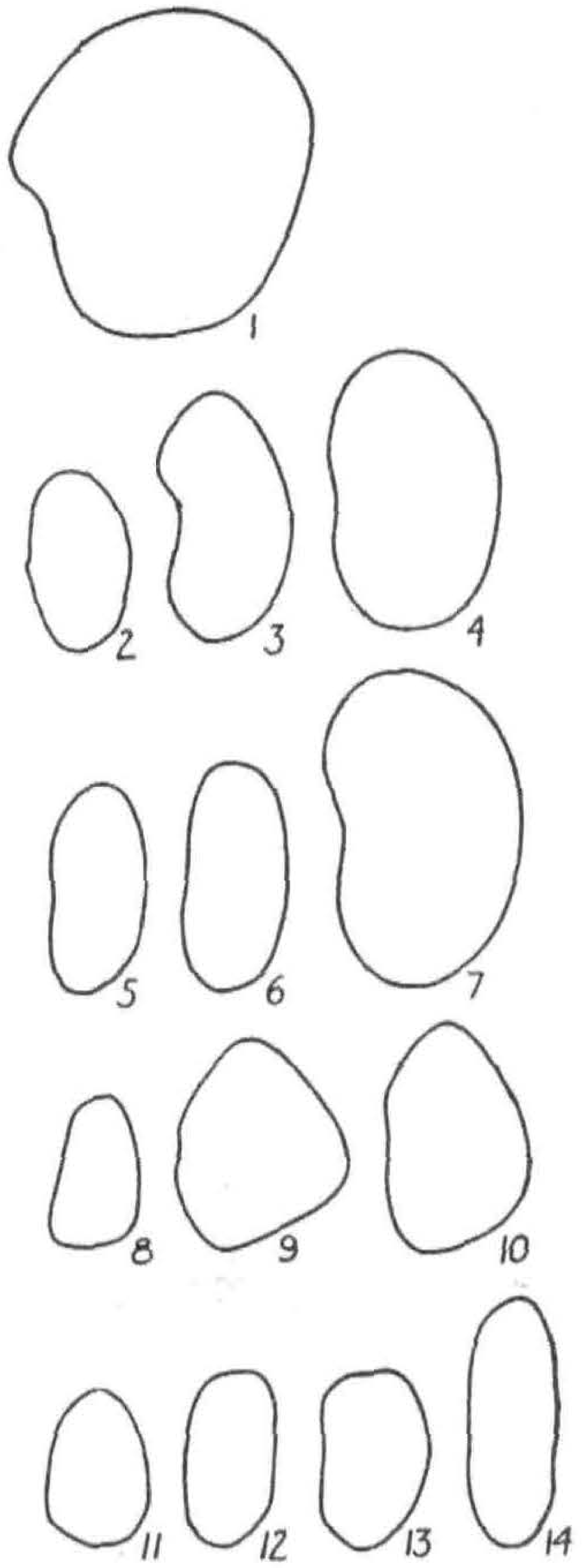


FIG. 180.—Types of bean seeds. 1, Broad Windsor; 2, White Narrow Field; 3, Dutch Case Knife Pole; 4, White Dutch Runner Pole; 5, Grenells Stringless Green Pod; 6, Long Yellow Six Weeks; 7, Long White Pole Lima; 8, Powell's Prolific Pole; 9, Dreer's Pole Lima; 10, Florida Butter Pole Lima; 11, Yellow Cranberry Bush; 12, Horticultural Wax; 13, Red Mexican; 14, French Kidney. (*Modified after Tracy, U. S. Dept. Agri.*)

KEY TO IMPORTANT SPECIES OF VICIA

Plants erect, smooth, or only slightly hairy, seldom tendril-bearing; flowers whitish with dark blue spots on each wing, *V. faba* (broad or Windsor bean).
Plants weak, usually hairy, tendril-bearing; flowers purplish.

Leaves rounded at tip; flowers many, in long one-sided racemes (Fig. 182), *V. villosa* (hairy vetch).

Leaves truncate at tip; flowers few, usually two in each leaf axil, *V. sativa* (vetch).

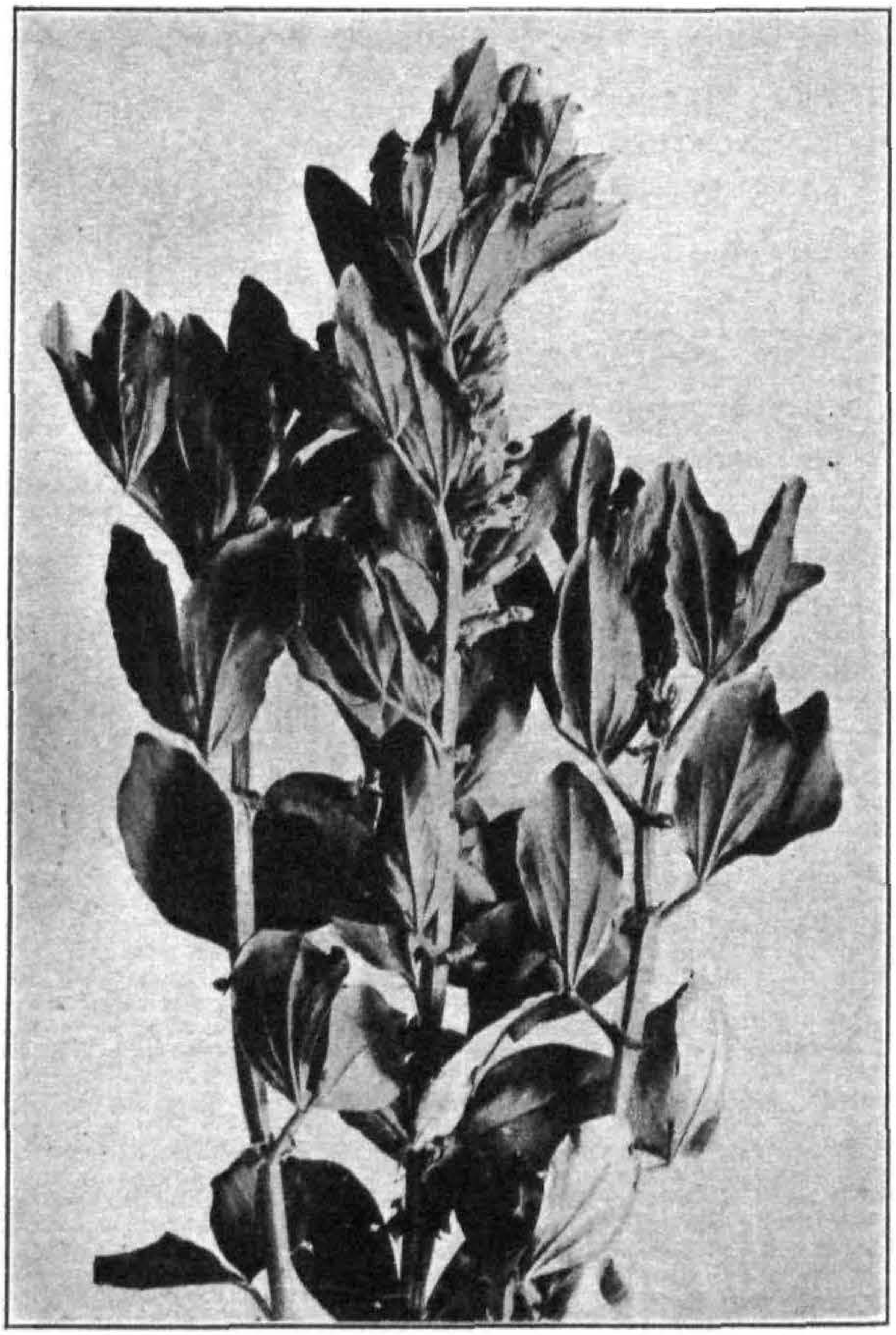


FIG. 181.—Broad or Windsor bean (Vicia faba).

Less Common Species.—There are a number of other *Vicia* spp. that are cultivated to some extent, as follows: *Narrow-leaved vetch* (*Vicia angustifolia*) is a native of the eastern United States, and is grown somewhat in Georgia as a hay crop. *Black bitter vetch* (*Vicia ervilia*) is an Asiatic species, cultivated somewhat as a winter green-manure crop in California. *Purple vetch* (*Vicia*

atropurpurea) resembles hairy vetch from which it differs, however, in being smooth. It is cultivated on the Pacific Coast and in the South. *Scarlet vetch* (*Vicia fulgens*), *Narbonne vetch* (*Vicia narbonnensis*) and *woolly podded vetch* (*Vicia dasycarpa*) are rather rare species, cultivated to a slight degree on the Pacific Coast.

The term "vetch" is given to a number of plants, not belonging to the genus *Vicia*, for example: Crown vetch (*Coronilla* sp.), kidney vetch (*Anthyllis vulneraria*), Dakota vetch (*Hosackia americana*) and *Lathyrus* spp.

VICIA FABA (Broad Bean, Windsor Bean)

This is a strong, erect annual, 2 to 4 feet high with a well-developed primary root (Fig. 181). The *leaves* are pinnately compound, and become blackish on drying. The *inflorescence* is an axillary raceme of two to six flowers. The *flower* is white, its wings marked by a large black spot. The *pods* are large and thick, and vary considerably in length, each bearing a number of large, black seeds. The smaller-seeded sorts, sometimes known as pigeon bean, field bean and tick bean, are used as an amimal food, while the large-seeded varieties are used as human food.

The home of the wild plant from which the cultivated varieties are derived is Algeria. Broad bean is cultivated chiefly in Canada. It thrives best where the summers are long and cool.

VICIA SATIVA (Common Vetch or Tares)

This is an annual climbing plant which branches freely. The *leaves* are pinnately compound with about seven pairs of leaflets, and a terminal tendril. *Flowers* occur singly or in twos in the leaf axils; they are short—peduncled, and reddish purple (rarely white) in color. The flowers are cross-fertilized. The hairy *pods* have four or five smooth, globular, gray or marbled seeds. The Willamette Valley, Oregon, produces a large proportion of the common vetch seed in the United States. Vetch seed loses its viability very rapidly

after about the third year. The plant is a native of Europe. It has become naturalized in many parts of the United States, occurring in fields and waste places. Common vetch is sown either as a winter or spring annual. If the winters are severe it is planted in the spring. This is the practice in the Northern States. However, in the south, where the winters are mild, it is planted in the fall. It is adapted to a light soil. It is intolerant of a poorly drained soil. The poorer soils of the East, deficient in lime, will support a fair crop. There are numerous varieties of the common vetch. Spring and winter varieties are recognized. The white or pearl vetch has white flowers and seeds.

Uses.—Common vetch is grown in the old country, and to an increasing extent in United States, as a hay crop. When grown for this purpose it should be cut when in bloom. The seeds are sometimes made into a flour. The species is also being recommended as a cover crop for orchards, and as a green manure.

VICIA VILLOSA (Hairy, Hungarian, Russian, Siberian, or Villous Vetch)

Hairy vetch (Fig. 182) is an annual or biennial, hairy plant naturally suited to cool temperate regions. The plants may grow to a length of 12 feet or more, but seldom to any considerable height on account of the weak stems. There is an extensive and deep root system which in the early stages of growth, particularly, constitutes a large proportion of the total weight of the plant. There are five to eight pairs of *leaflets*, and many (about thirty) violet-blue, rarely white, *flowers* in one-sided racemes. Cross-fertilization is necessary for the normal production of seeds. Bees are the chief agents in the dissemination of pollen. The *pods* are smooth, pale in color, and contain two to eight small globular black seeds. The cotyledons remain underground at germination, as is the case in the common garden and field pea. Hairy vetch is a

native of Europe and Asia. It is much hardier than common vetch, and consequently can be grown at higher latitudes.

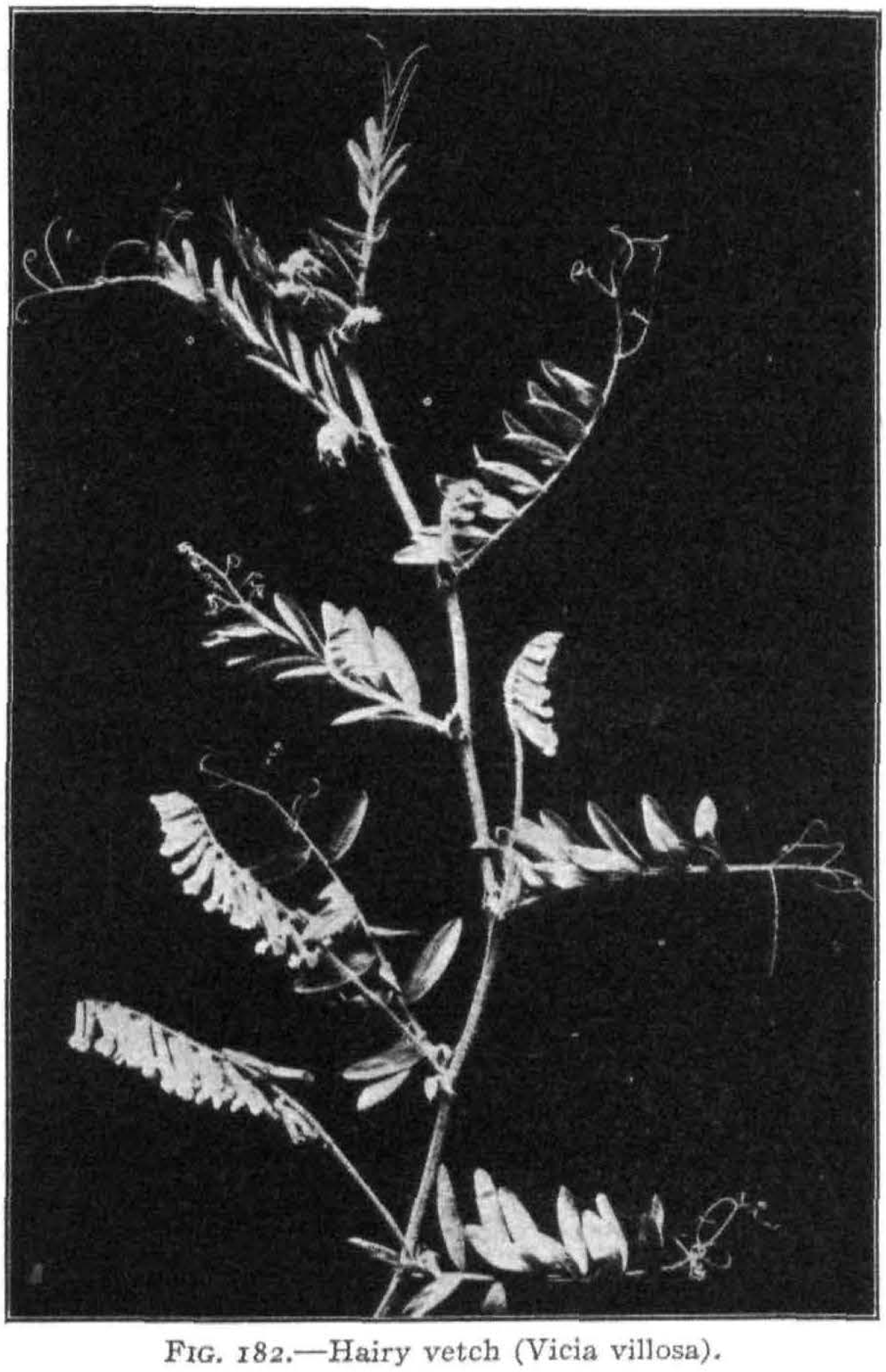


FIG. 182.—Hairy vetch (Vicia villosa).

Moreover, it is more drought-resistant and tolerant of alkali. Hot summer weather is very harmful to its growth. It is frequently planted on light, sandy soils, where it may be plowed under as a green manure.

The plant has a variety of uses: hay, pasturage, cover crop, silage, and green manure. It is usually cut for hay about the time the first pods are full grown. The quality of the hay decreases after this period.

LATHYRUS (Vetching, Wild Pea)

This genus resembles *Vicia*. The leaflets are broader, as a rule, however, the flowers are larger, and the stigma is hairy along the inner side (Fig. 176, B).

There are over 100 species of *Lathyrus*, natives of the Northern Hemisphere and of South America. There are numerous wild sorts in the United States. The two most common species are *Lathyrus odoratus*, the common sweet pea, and *Lathyrus latifolius*, the everlasting or perennial pea. *Lathyrus odoratus* is an annual, bearing two to four flowers on a peduncle, and pods 4 to 5 inches long. The following *Lathyrus* species are of forage value and are now planted to some extent in this country: *L. tingitanus* (Tangier pea), *L. cicera* (flat-podded pea) and *L. ochrus* (ochrus).

TRIFOLIUM (Clover)

Generic Description.—Representatives of this group are annual (crimson clover) or perennial (white clover) herbs with palmately trifoliate (hence the name, *Trifolium*) *leaves* (Fig. 183), the stipules of which are adnate to the petiole. The *inflorescence* is a dense spike or head. The *flowers* vary in color. The *calyx* is persistent, its teeth nearly equal, and usually bristle-form. The *corolla* is also persistent, sometimes grown fast to the tube of filaments. The *stamens* are diadelphous (nine and one). The *ovary* is sessile or stipitate, and few-ovuled. The *pods* are small, membranaceous, mostly one-seeded (rarely more), indehiscent or opening circularly. The *seeds* are small and kidney-shaped.

Geographical.—There are close to 300 species of *Trifolium*, most of which occur in the north temperate regions; a few, however, also occur in South America and South Africa. They are distributed from low to high altitudes. Besides those given in the following key, two others, *T. suaveolens* (Shaftal or Persian clover) and *T. alexandrinum* (Berseem) are grown to some extent in the United States.

KEY TO PRINCIPAL SPECIES OF TRIFOLIUM

Flowers in spike-like heads, much longer than thick, *T. incarnatum* (crimson or scarlet clover).
Flowers in globular or ovoid heads.
  Corolla white or yellowish-white, sometimes touched with pink; stems creeping, *T. repens* (white clover).
  Corolla red, red-purple, or rose-colored; stems erect or nearly so.
    Flowers pedicelled; stipules acuminate (Fig. 183, A), *T. hybridum* (Alsike or Swedish clover).
    Flowers sessile; stipules abruptly acute (Fig. 183, D).
      Blade of leaflet marked with large spot; heads sessile, *T. pratense* (red clover).
      Blade of leaflet without spot; heads stalked, *T. medium* (mammoth or zigzag clover).

TRIFOLIUM REPENS (White or Dutch Clover)

Description.—This is a low, smooth, perennial herb arising from a straight tap root. The root system is shallow. The plant possesses creeping *stems* which develop adventitious roots at the nodes. The long-petioled, trifoliate *leaves* have inversely heart-shaped or notched leaflets and narrow, membranous stipules. The *inflorescence* is a head and is borne on a long flower stalk which arises in the leaf axils. The *flowers* are small, fragrant, and white or pinkish. They are erect at first, but become deflexed when mature. The visitation of insects is necessary for the production of a good crop of seed. The small *pods* are usually four-seeded. The seeds vary a great deal in their longevity. Germination of so-called "hard seeds" may be delayed several years in the soil. Such seeds usually show up in germination tests.

Geographical, and Uses.—White clover has become distributed throughout the greater part of temperate North America, Europe, and Asia. It is common in lawns, pastures, and meadows, and is an important ingredient of lawn grass mixtures. The only distinct agricultural variety is Ladino clover (*Trifolium repens latum*). It is larger than ordinary white clover, and less resistant to cold.

Environmental Relations.—White clover will withstand greater temperature extremes than either red clover or alsike clover. It is naturally suited to cool, moist regions. It is more tolerant of shade than red and alsike clovers.

TRIFOLIUM HYBRIDUM (Alsike, Alsatian, or Swedish Clover)

Description.—Alsike is an erect, branching, rather stout, almost glabrous perennial, 1 to 3 feet tall. Its life period is from four to six years. There are many secondary roots which soon become as large as the main tap root. The *leaves* are long and have greenish veins, long taper-pointed stipules (Fig. 183, A), and obovate leaflets. The plant is more leafy than red clover. The plant is usually cut for hay when in full bloom. The flowering heads are on long peduncles which arise from leaf axils. The *flowers* are pedicelled, and white or pinkish. The *pods* are two- to four-seeded. The seeds lose their viability rapidly after the second year.

Geographical, and Uses—Alsike clover is a native of Europe. It has been introduced into this country for agricultural purposes and has escaped from cultivation, often being found in fields and waste places. It is not a hybrid between white clover and red clover, as formerly thought. The plant is grown in the same manner and for the same purposes as red clover. The plant is very hardy, more so than red clover, and is quite frequently mixed with timothy for planting at high altitudes and latitudes. It is prized as a honey plant.

TRIFOLIUM INCARNATUM (Crimson, Scarlet, or Italian Clover)

Description.—This is an erect, soft-hairy annual, 6 to 36 inches high. The *leaves* are long petioled; the stipules are broad and with dark purple margins; the leaflets are

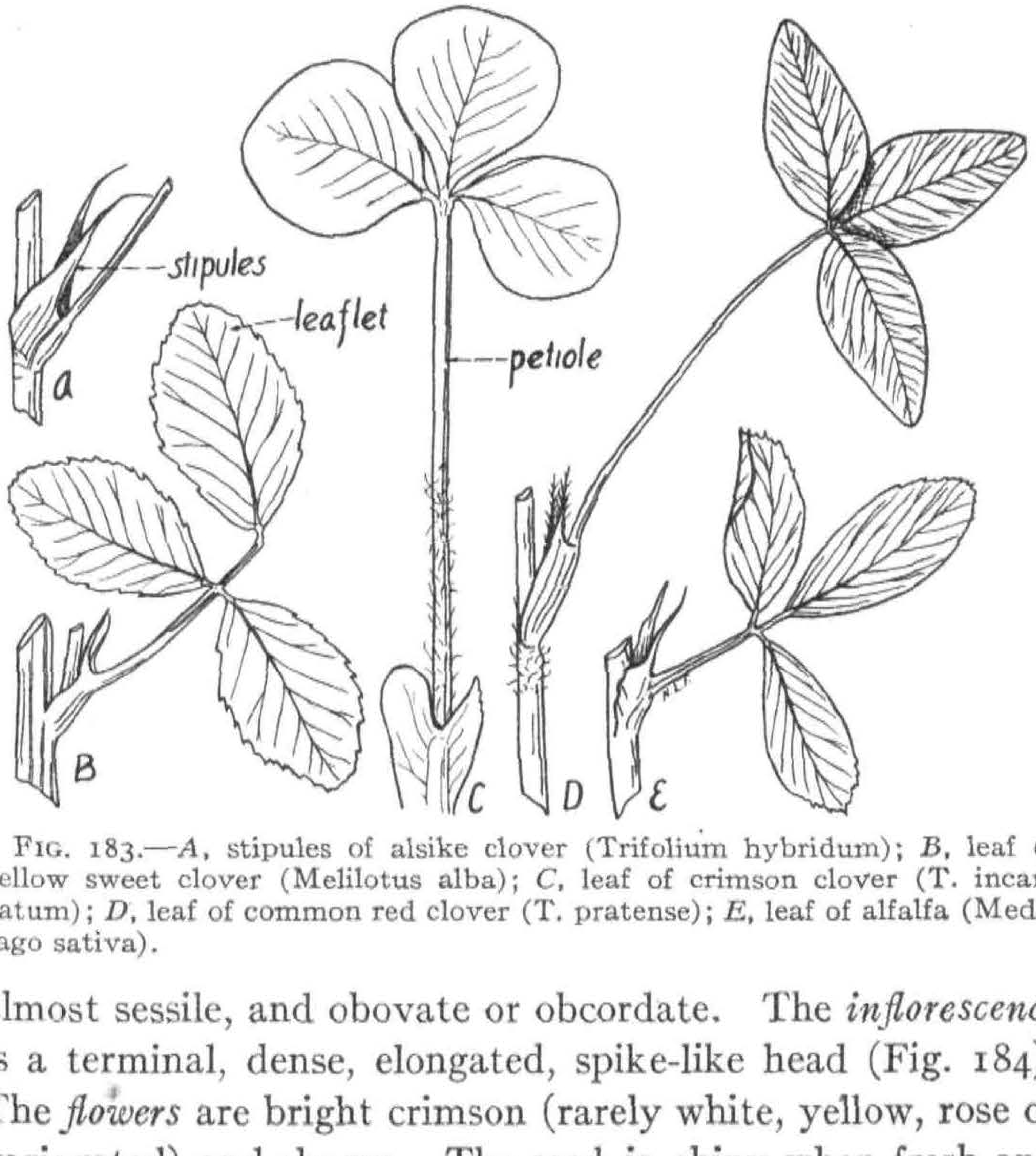


FIG. 183.—*A*, stipules of alsike clover (Trifolium hybridum); *B*, leaf of yellow sweet clover (Melilotus alba); *C*, leaf of crimson clover (T. incarnatum); *D*, leaf of common red clover (T. pratense); *E*, leaf of alfalfa (Medicago sativa).

almost sessile, and obovate or obcordate. The *inflorescence* is a terminal, dense, elongated, spike-like head (Fig. 184). The *flowers* are bright crimson (rarely white, yellow, rose or variegated) and showy. The seed is shiny when fresh and pinkish in color.

Geographical, and Uses.—Crimson clover is a native of Europe. It has become naturalized in the eastern portions of the United States, where it occurs quite commonly in waste places. The plant is grown in this country mainly

as a crop for hay, forage, or silage. It also has some value as a soiling crop and as a cover crop. The hay sometimes proves dangerous to horses, due to the tendency of the hairy calyces to form indigestible masses in the stomach of the animal, especially if the plants are too ripe when cut. These hair balls seldom form in the stomachs of cattle and sheep.

Environmental Relations.—Crimson clover is less resistant to low temperatures than any of the other common clovers. It is grown with success in orchards, because of its shade tolerance. Although it prefers sandy soil, it will do well in soils of heavier type.

TRIFOLIUM PRATENSE (Common Red or Purple Clover)

Stems and Roots.—This is a perennial plant, more or less hairy, branching, decumbent or erect, 6 to 24 inches tall, rising from the thick crown. The life period is a varietal character. The average is about two years. It develops from a strong *tap root* which possesses an extensive system of laterals. The tap root reaches a depth of 3 or 6 feet. It draws moisture and mineral nutrients from the lower soil layers. In general there is about 1 pound of root to 2 pounds of plant above ground. This means that the clover crop leaves considerable organic matter in the soil.

Leaves.—The leaves are of the clover type, with hairy-margined leaflets and large conspicuously purple-veined stipules. The leaflets often bear a pale spot in the center.

Inflorescence and Flowers.—The terminal *inflorescences* are ovate (Fig. 184). Each inflorescence has from 35 to 150 purple-rose flowers. The second crop usually has more flowers per head than the first crop. The *flowers* are of the ordinary pea type, except that the petals are united at their bases and to the staminal tube to form a corolla-tube about ½ inch long.

Fruit.—The *ovary* develops into a capsule, bearing one seed. There are two ovules in each ovary, but only one, as a rule, matures into a seed. Infertile ovules are quite com-

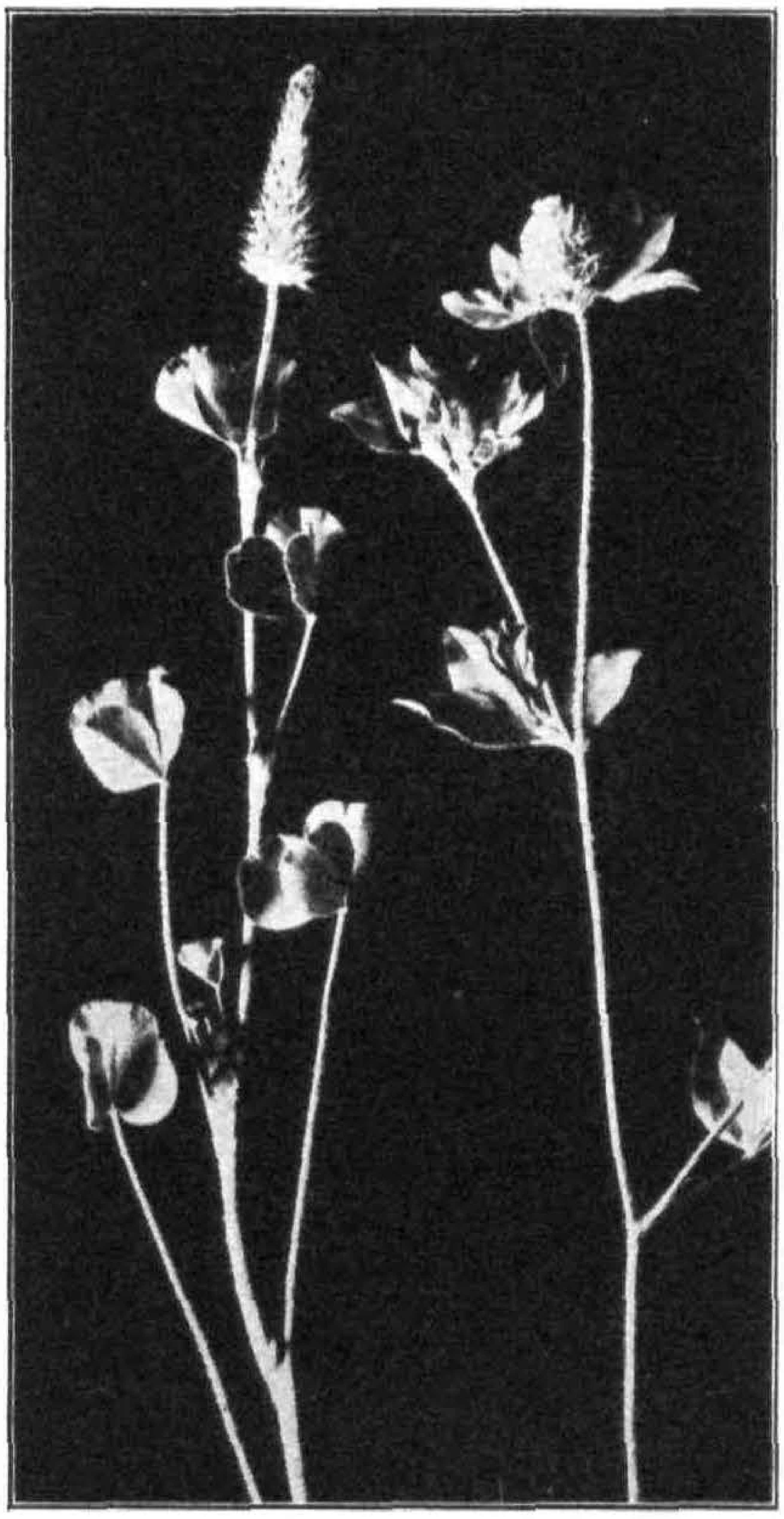


FIG. 184.—Crimson clover (Trifolium incarnatum), on left; common red clover (T. pratense), on right.

mon in red clover, the larger percentage usually being in the first crop. This is probably one of the chief reasons why the second crop of clover is more commonly used for seed. An additional advantage in harvesting the second crop for seed rather than the first is that the farmer is able to get two

crops in a season, for if the first crop is allowed to seed, there is insufficient food supply, and in some instances a season too short, for the development of a vigorous second growth. In addition to the reason given above for the relatively light yield of seed in the first crop, it is claimed that pollinating insects are not abundant enough, and that the plant is occupied with the production of new shoots rather than reproductive activity. In general, a rank-growing plant is not a good seed producer.

When the *capsule* is mature, the stylar end separates from the basal part by an irregular transverse line. The upper part of the capsule, together with the style, comes off as a lid (Fig. 185), and the single seed escapes. The *seeds* are kidney-shaped, and yellow, or mixed yellow and violet in color.

FIG. 185.—Fruit of red clover (Trifolium pratense), much enlarged.

Pollination.—Red clover flowers are protandrous. The work of Westgate and Coe establishes the fact that "red clover flowers must be cross-pollinated in order to set seed on a commercial basis." The pollen must come from a separate plant, for even when taken from flowers of the same plant, the percentage of seed set is very small. The bumblebee (*Bombus*) is the most important insect visitor of the red clover. It is capable of pollinating 30 to 35 flowers a minute. Honey bees are also efficient pollinators. When the bumblebee lights on the clover head and inserts its proboscis into the staminal tube, its weight presses down on the keel and wings of the flower, from which nectar is being taken, thus forcing out the stigma and anthers up against the bee's head. The stigma becomes dusted with pollen from another flower and the anthers open, leaving pollen on the under side of the bee's head. The flower parts return to their original position when the bee

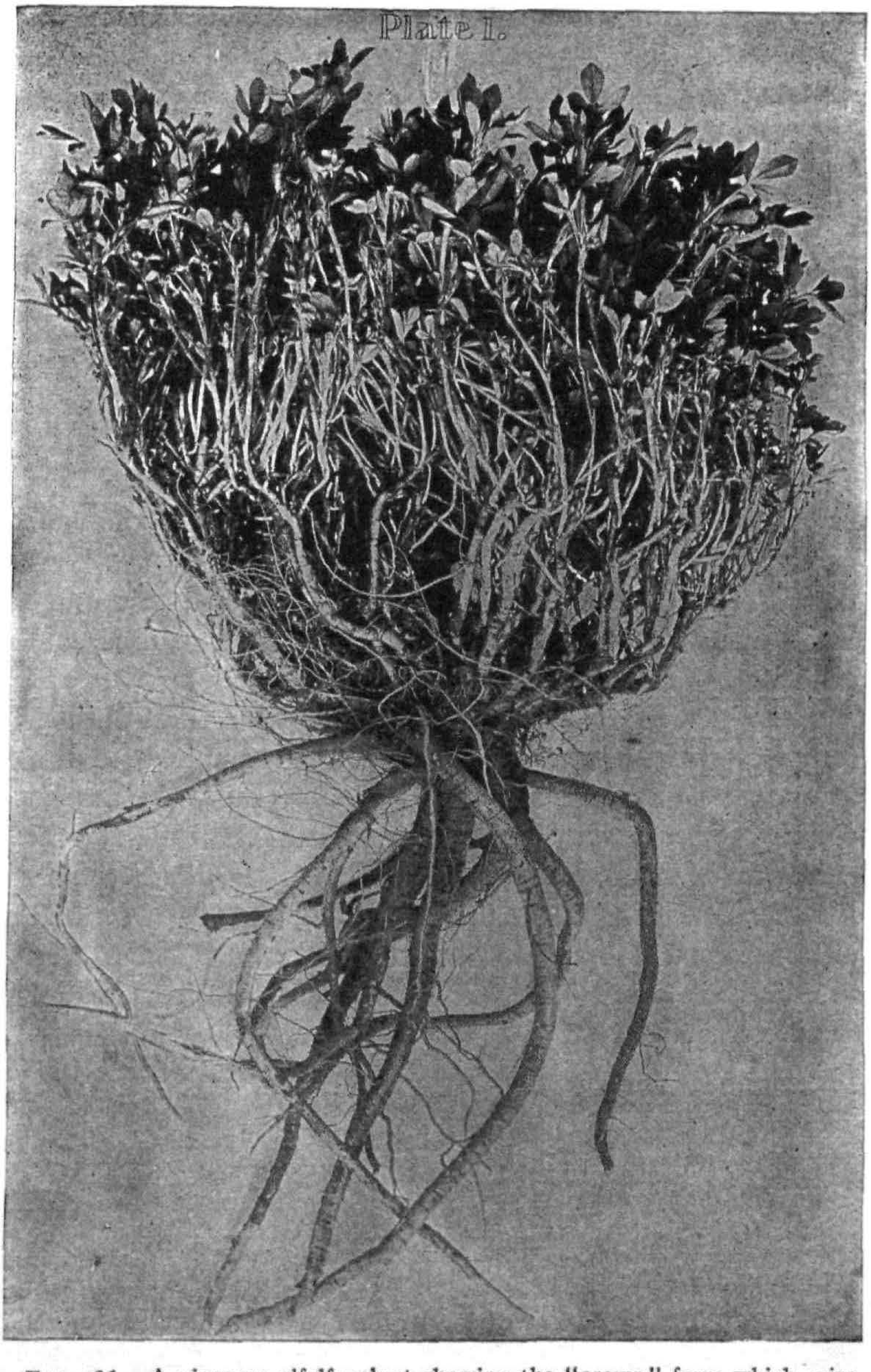


Fig. 186.—A vigorous alfalfa plant showing the "crown" from which arise the numerous shoots. (*After Headden, Colo. Agr. Exp. Sta.*)

leaves the flower. Nectar sought by the bee is secreted at the bases of the stamens, and collects in the staminal tube.

Geographical.—The species is a native of Eurasia. It has become naturalized in the United States, occurring commonly in the fields and meadows throughout most of our area.

Environmental Relations.—Red clover attains its best growth in humid sections of the country, and where the summer and winter temperatures are not extreme. Unlike alfalfa, dry atmospheric conditions are detrimental to red clover; but like alfalfa it requires lime in the soil. Moreover, it is intolerant of a poorly drained soil and of much shade.

Mammoth Clover.—This clover, sometimes known as perennial clover, sapling clover, pea-vine clover, and bull clover, is a form of the ordinary *Trifolium pratense;* as compared with the latter, mammoth clover matures later, has a more highly branching tap root, longer pedicels, and solid stems. It is known as *Trifolium pratense perenne.*

Uses.—Common red clover is one of our most prized forage and hay crops; it is also raised to some extent as a green-manure and cover crop. Its importance as a crop in the United States may be judged from the fact that the total acreage is about five times that of alfalfa. It is adapted to the humid sections of the country. The highest percentage of digestible substances occurs in the plant just before full bloom. The plant soon becomes tough and fibrous after the blooming period.

TRIFOLIUM MEDIUM (Zigzag, Medium Red, White, Mammoth or Meadow Clover)

This is a perennial clover resembling red clover (*T. pratense*), described above. The plant is larger, however, its stems are more spreading and bent more zigzag at the nodes; the leaflets are longer and narrower, and the stipules

longer and more pointed. The leaflets are lanceolate or oblong and not spotted as in the red clover. The flowers are bright purple.

This species is a native of Siberia and possibly Europe. It has gained entrance into this country and occurs here and there in the eastern United States as a ruderal.

The plant is being grown in the same manner and for the same purpose as common red clover.

MEDICAGO (Medics)

Generic Description.—The medicagos are mostly herbs, sometimes woody at the base, as in common alfalfa, and very rarely shrubby (one species in southern Europe). The *leaves* (Fig. 183, E) are pinnately three-foliate, the stipules adnate to the petiole, and the leaflets commonly dentate, pinnately veined, with the veins terminating in the teeth. The *flowers* are small, yellow or violet, in axillary heads or racemes. The calyx teeth are short, and about equal in length. The *petals* are free from the staminal tube; the standard is obovate or oblong, the wings oblong, and the keel short and obtuse. The *stamens* are diadelphous (nine and one). The ovary is sessile or short-stipitate, and several- or rarely one-ovuled; it has a subulate (awl-shaped), and smooth style. The *pods* (Fig. 187) are curved or spirally twisted, veiny or spiny, and indehiscent.

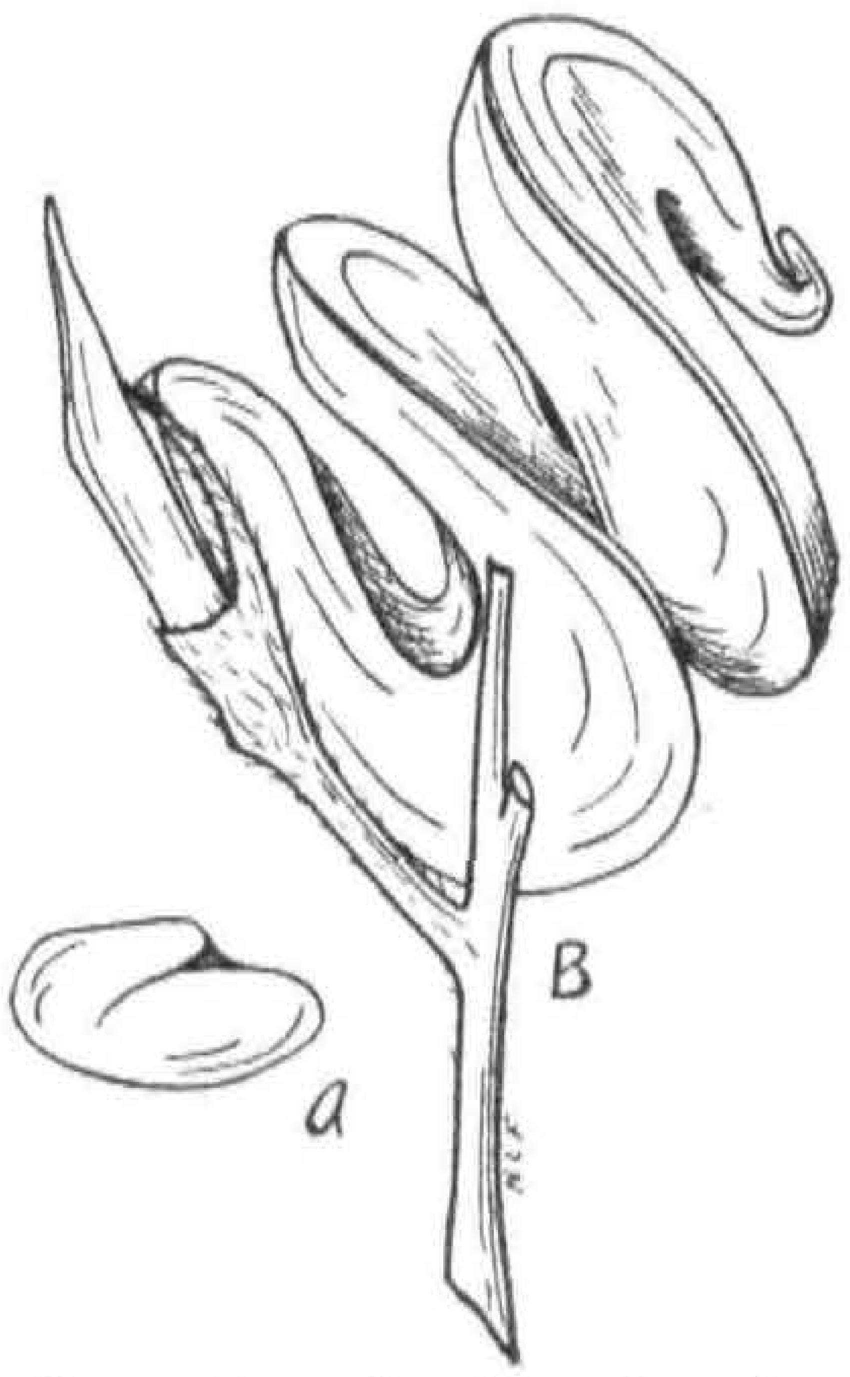


FIG. 187.—Seed and pod of alfalfa (Medicago sativa). × 5.

Geographical.—There are a number of species of *Medicago*, all of which are native to the eastern hemisphere. They naturally range from Eastern Asia to Southern Africa. There are seven perennial species of *Medicago*, and about 37 annual species, one of which, yellow trefoil (*Medicago lupulina*),

has a biennial or possibly perennial form. The nonperennial species are commonly known as "bur clovers." They will grow naturally as winter annuals.

KEY TO PRINCIPAL SPECIES OF MEDICAGO

Perennial, erect-growing plants; flowers violet, *Medicago sativa* (alfalfa).
Annual, low-growing plants; flowers yellow.
  Pods kidney-shaped, without spines, *Medicago lupulina* (hop clover).
  Pods cylindrical, with spines.
    Stems pubescent; pods 3½ to 5 millimeters diameter; purple spot in center of each leaflet; two to eight seeds in each pod, *Medicago arabica* (spotted bur clover).
    Stems glabrous, pods 7 to 10 millimeters diameter; no purple spot in center of each leaflet; three to five seeds in each pod, *Medicago hispida* (toothed bur clover).

MEDICAGO SATIVA (Alfalfa, Lucerne)

Roots.—Alfalfa is a deep feeder. The young plant usually sends down a single tap root. As a rule, this takes a straight downward course. In many cases there is an abundance of small laterals just below the crown and to a depth of 1 to 2 feet. In other instances, comparatively few laterals are given off. Headden found in a plant only nine months old, that the young roots had extended to a depth of over 9 feet. Ordinarily the weight of roots exceeds weight of top.

Stems.—Alfalfa is an ascending or erect perennial. Its life period is dependent upon environmental conditions and the variety. The average life is from five to seven years. Fields 20 to 25 years old are found in the semi-arid sections. At or near the ground level, is a short, compact stem (crown) from which the numerous (20 to 50) branches arise (Fig. 186). has been shown that there is a well-defined relationship between the nature of the crown and hardiness. Non-hardy types of alfalfa have an upright-growing crown with but few buds and shoots developed below the soil surface. The crown of hardy types is more spreading and the numerous buds and shoots come from below the soil surface. Hence in

the latter case, the buds and young shoots are protected by the soil from winter freezing. These hardy types are Grimm and Baltic strains. The stems of alfalfa are rather slender and freely branching. Common alfalfa has no rootstocks. Some forms of *Medicago falcata* possess them, however, and they also occasionally appear in some variegated types.

"Cuttings" of Alfalfa.—The number of "cuttings" of alfalfa depends upon the length of the growing season, and the water supply. Three cuttings are usually made throughout most of the alfalfa-growing regions of the United States. In the Imperial Valley, California, ordinary alfalfa has yielded as many as nine cuttings in a year. This practice indicates that alfalfa has the capacity of sending up numerous shoots from the crown. The shoots of a second or third crop begin to appear about the time the plant is coming into bloom, and it is the usual practice to cut the crop at this time, so that the food supply that would normally go into developing fruit and seed, is diverted to the young growing shoots of the succeeding crop. Furthermore, the leaves are richest in nutritive substances when the plant is in bloom. The leaves contain about 80 per cent. of the protein in the plant, hence methods of harvesting should look toward the prevention of their loss. The different cuttings of alfalfa vary somewhat in quality and chemical composition. However, more data are needed to determine the relative feeding value of the different cuttings.

The alfalfa plant is a heavy feeder. According to Ames and Boltz, a 3-ton yield of alfalfa hay contains 163 pounds of nitrogen, 17 pounds of phosphorus, 99 pounds of potassium, and 90 pounds of calcium.

Leaves.—The alternately arranged leaves are trifoliate (Fig. 183, E). They are oblong in general outline and sharply toothed along the margin; the tip is terminated by a projecting midrib. The stipules are prominent.

Inflorescence.—This is a dense raceme springing from the axils of the branches.

Flowers.—The ordinary color of the flower is purple or violet, but in variegated types, may be blue, green, or yellow. The calyx teeth are longer than the tube of the calyx. The standard is somewhat longer than the wings, which in turn surpass the keel. The staminal tube is held in a state of tension by two opposite lateral projections on the inside of the keel (Fig. 188).

Pollination (Fig. 188).—Alfalfa possesses a mechanism for the explosive dispersal of its pollen. When the edges of the keel are spread apart, the staminal tube is released, and both the pistil and stamens snap up against the standard. The pollen is scattered in this process. The process is called "*tripping*." Alfalfa flowers are usually tripped by visiting insects, chiefly bumblebees and leaf-cutting bees (*Megachile*). The weight of an insect may be sufficient to cause a separation of the keel edges, and consequently "tripping." Usually, however, the separation is brought about by the protrusion of the insect's proboscis between the edges of the keel. It has been observed that alfalfa flowers may be tripped without the visitation of insects. This is termed "automatic" tripping. Humidity and temperature conditions are probable causative factors in automatic tripping.

Both self- and cross-pollination are effective in alfalfa. Self-pollination usually results from automatic tripping. It is known that good seed crops are produced in regions where tripping insects are scarce. However, the number of pods set and the number of seeds per pod are increased if cross-pollination (xenogamy) is accomplished.

Factors Affecting Seed Production.—As has been stated, cross-pollination results in a greater crop of seed than self-pollination. An abundance of tripping insects may increase considerably the seed output; however, good seed

crops occur in regions where tripping insects are scarce. Seed production is usually light in humid sections of the country. Moreover, too much irrigation water applied during the flowering period is detrimental to seed production.

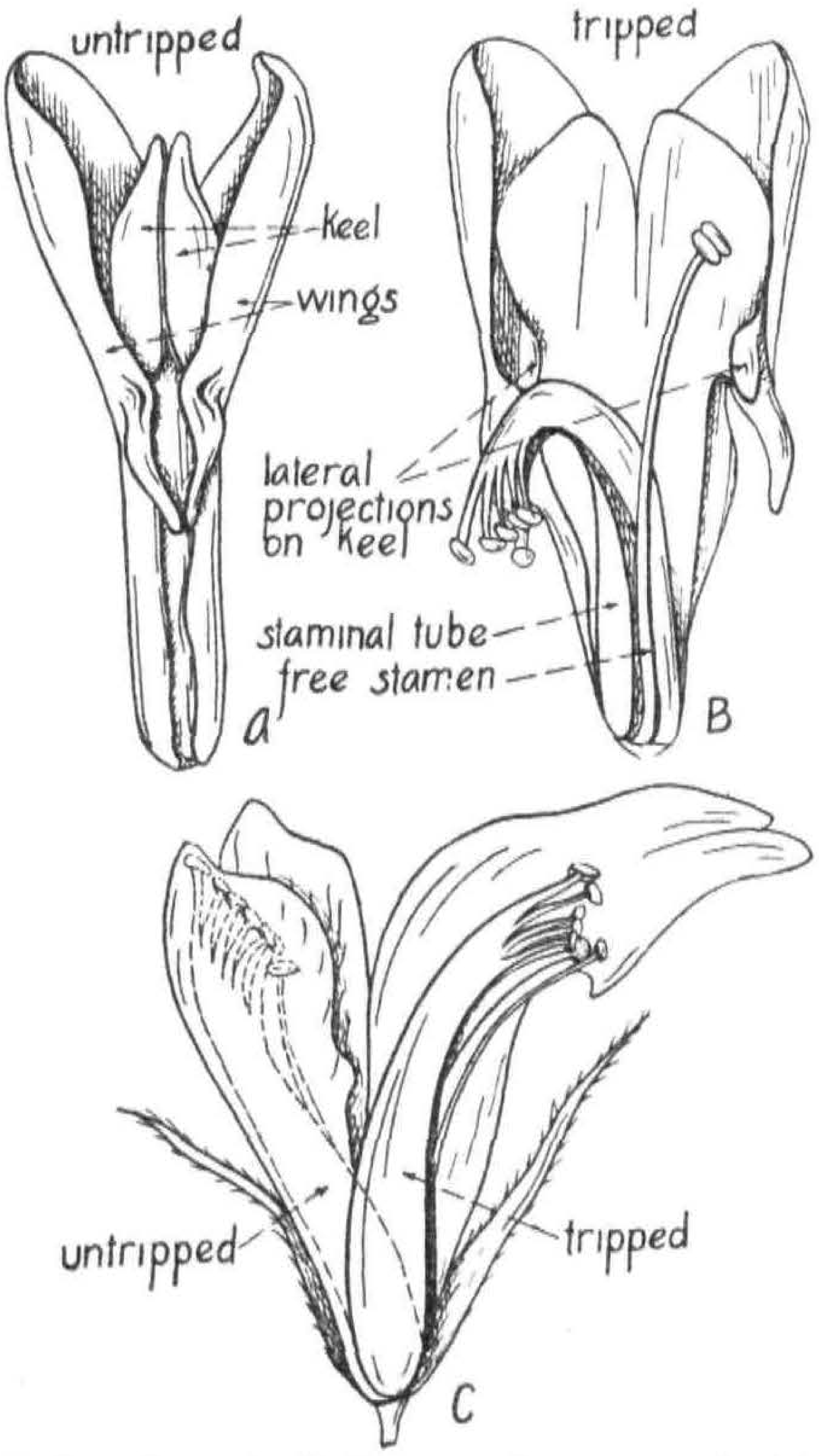


FIG. 188.—Pollination of alfalfa. *A*, flower untripped with calyx and standard removed; *B*, same tripped; *C*, position of staminal tube untripped and tripped. (*After U. S. Dept. Agri.*)

The heaviest yields of alfalfa seed occur in the arid sections of Kansas, Colorado, Utah and Idaho. Isolated plants invariably produce a greater crop of seed than those in a thick stand. The sun's heat favors automatic tripping.

Martin finds that the setting of seed pods in alfalfa is largely dependent upon the proper functioning of the pollen. The pollen grains require a certain amount of water to germinate. When a pollen grain comes to the stigma, the amount of water it finds there depends upon the moisture delivery of the stigma and the moisture of the air. The supply of water for germination of the pollen grains may be changed by increasing the water in the soil, or the atmospheric humidity about the plant.

Fruit.—This is an indehiscent legume, coiled two or three times (Fig. 187). There are one to eight seeds in each pod; they are kidney-shaped, and about 1/8 inch long. The seeds retain their viability for many years.

Germination and Seedling.—The young seedling consists of two short cotyledons, a hypocotyl, and a tap root. The first foliage leaf is simple, while the second, third, and all others are trifoliate. There is soon formed an erect stem with but few branches; hence the first growth looks thin. However, there spring up later numerous branches from the lowermost nodes and from the axils of the cotyledons. The result is a well-developed "crown."

Geographical.—Common alfalfa is a native of temperate western Asia. The original home is probably from northern India to the Mediterranean region. It is now being cultivated in many parts of the world, and wherever so cultivated, frequently escapes and becomes a ruderal.

Types of Alfalfa.—*Medicago sativa* is now quite generally considered to be an heterogeneous species, made up of many strains, varieties, and even subspecies. Westgate holds that some of our hardy strains of alfalfa (Grimm, for example) owe their hardiness to the possession of a small percentage of the "blood" of the hardy yellow-flowered or sickle alfalfa (*Medicago falcata*). Numerous forms of alfalfa arise where ordinary alfalfa (*M. sativa*) and yellow-flowered alfalfa (*M. falcata*) grow together. These hybrid forms are, of course,

unstable. They have been recrossed several times with ordinary alfalfa and also among themselves. Such forms have been termed "variegated alfalfas." Sand lucerne (*Medicago media*) is considered by some botanists to be a natural hybrid between *M. sativa* and *M. falcata;* others consider it to be a distinct species. Sand lucerne has flowers ranging from bluish and purple to yellow, with numerous intermediate shades. The seeds are not as heavy as those of common alfalfa. The plant is a hardy type. Grimm alfalfa, as has been indicated, is quite certainly a form with hybrid characteristics, the parents being common alfalfa and yellow-flowered alfalfa. Other well-known types of alfalfa are: Turkestan, German, American, Arabian, and Peruvian.

Turkestan was secured from Russian Turkestan in 1898. The water requirement of the plant is low, and it also possesses an ability to withstand extremes of temperature. The plant is ordinarily a little smaller, and the leaves are narrower and more hairy, than other common sorts. German alfalfa resembles Turkestan. It is less hardy, however, and is a poorer yielder than the American type. The latter is the most common western alfalfa. Arabian alfalfas are not resistant to cold, hence they are restricted to the warmer States, particularly Arizona, New Mexico, Texas, and California. Peruvian alfalfa is a productive sort adapted to growth under irrigation in the southwest, where the winters are mild. Brand proposes to place Peruvian alfalfa as a distinct variety (*Medicago sativa* var. *polia*). It is taller, less branched, and more rapid in its growth and recovery after planting than common cultivated alfalfas. Furthermore the flowers are slightly longer, and the floral bract is longer than either calyx teeth or calyx tube.

Environmental Relations.—Alfalfa is able to withstand high temperatures if the air is dry, but high temperatures accompanied by a humid air are decidedly injurious. For

this reason, it is particularly well adapted to the semi-arid sections of the United States, where it is grown both on irrigated and non-irrigated land. Its resistance to low temperatures is a varietal characteristic, and also somewhat dependent upon cultural operations. Grimm and Baltic types are less liable to suffer from winter killing than the so-called common alfalfas.

The following data shows the water requirement of alfalfas, in comparison with other crops (from Briggs and Shantz).

Crop	Water Requirement
Millets	310
Sorghums	322
Corns	368
Wheats	513
Oats	597
Potatoes	636
Alfalfa, Peruvian S. P. I. (30,203)	651
Alfalfa, Grimm S. P. I. (25,695)	963

In spite of its relatively high water requirement, alfalfa is able to withstand drought. This is due to its deep root system which draws upon the water in the lower strata of soil.

Alfalfa cannot withstand alkali, and suffers if soil drainage is not good. The plant requires lime in the soil. The soil type has considerable influence upon the form of the root system. A hard compact soil causes a more or less branching root system, while in a loose soil the tap root system is typically developed.

Uses and Production.—Alfalfa is the most important hay crop in the Western States. The total number of acres in alfalfa in the United States, 1919, was 8,629,111; of this number, the Western States furnished 7,392,374 acres. The five leading States, 1919, named in the order of their alfalfa production were Kansas, Nebraska, Colorado, California and Idaho.

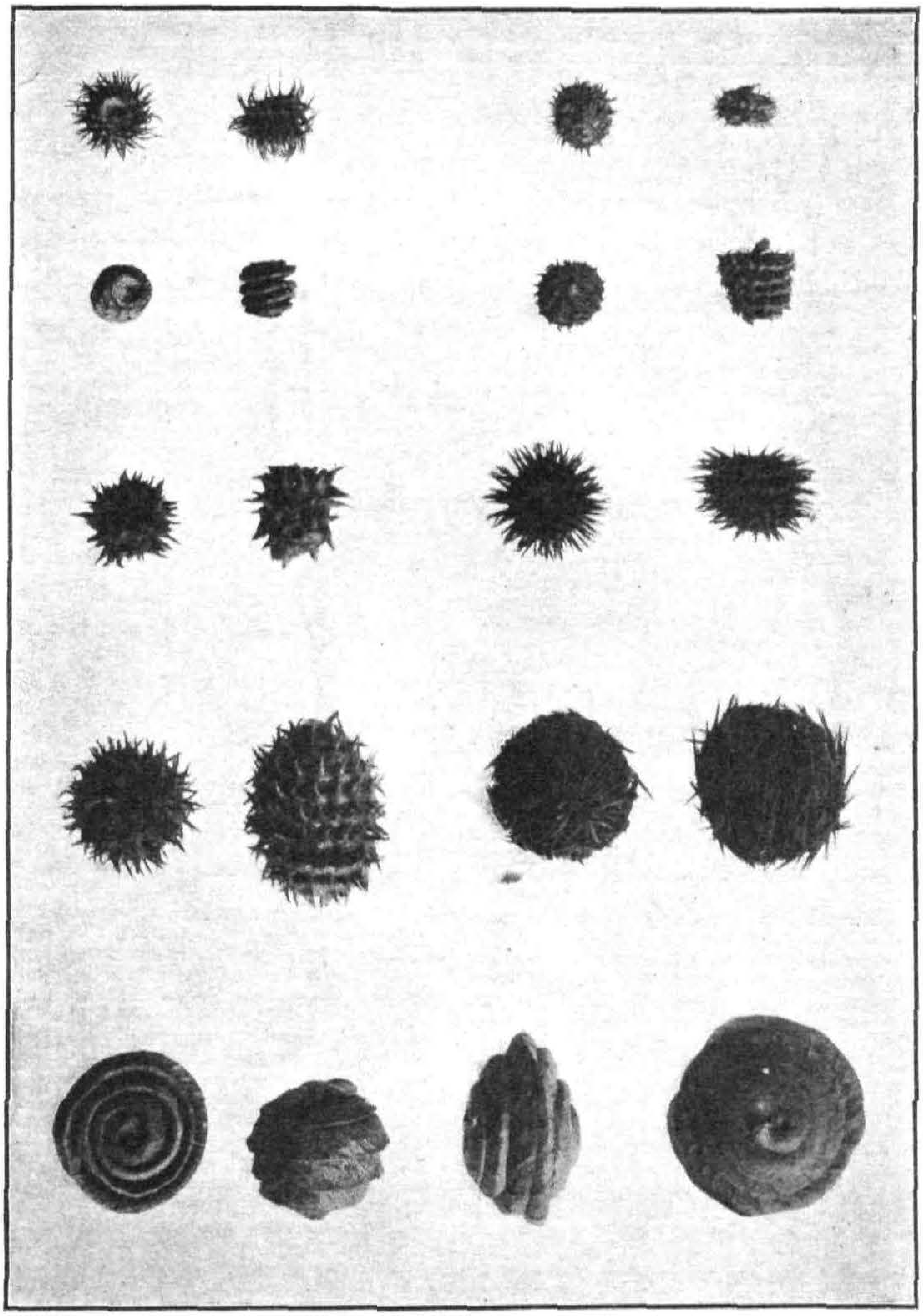


FIG. 189.—Pods of 10 species of Medicago. Top row, M. arabica and M. hispida denticulata; second row, M. hispida confinis and M. hispida terebellum; third row, M. muricata and M. hispida nigra; fourth row, M. ciliaris and M. echinus; bottom row, M. scutellata and M. orbicularis. *(After McKee and Ricker, U. S. Dept. of Agr.)*

MEDICAGO LUPULINA (Hop Clover, Black Medic, Yellow Trefoil)

This plant is usually annual, sometimes perennial. The stems are four-angled, pubescent, and branched at the base, the branches being decumbent and spreading. The petioled *leaves* have small obovate, oval or orbicular, denticulate or crenulate leaflets. The *flowers* are small, yellow, in dense, oblong or cylindrical heads. The *pods* are black, curved, strongly veined, and one-seeded.

The plant is a native of Eurasia. It is now found throughout the greater part of the United States and other temperate regions where it occurs in fields and waste places. It is sometimes planted on poor soil, and has some promise as a green manure.

MEDICAGO ARABICA (Spotted Bur Clover)

This is a smooth annual plant with procumbent stems. The *leaflets* have a dark purple spot in the center. The *pods* (Fig. 189) are in long clusters, twisted into three to five spirals, and the edges bear numerous grooved spines which interlock. The *seeds* are kidney-shaped, and about 2½ millimeters long. *Medicago arabica inermis* is a spineless-podded form.

Spotted bur clover is a native of Europe and Western Asia. It is introduced into the United States and occurs on the Atlantic, Gulf, and California coasts. It is being used as a pasturage crop.

MEDICAGO HISPIDA (Toothed Bur Clover)

Toothed bur clover (Fig. 190) is a smooth, annual plant with decumbent leaves. The *leaflets* often have small whitish and dark red spots scattered over the surface, which disappear with age. The *flowers* are yellow. The *pods* are netted-veined, twisted spirally, and spiny. The seeds are light- to

brownish-yellow, kidney-shaped, and about 3 millimeters long. *Medicago hispida reticulata* and *M. hispida confinis* are forms with spineless pods. Toothed bur clover, *Medicago hispida denticulata*, is native to the northern Mediterranean region. It is the most common bur clover grown in

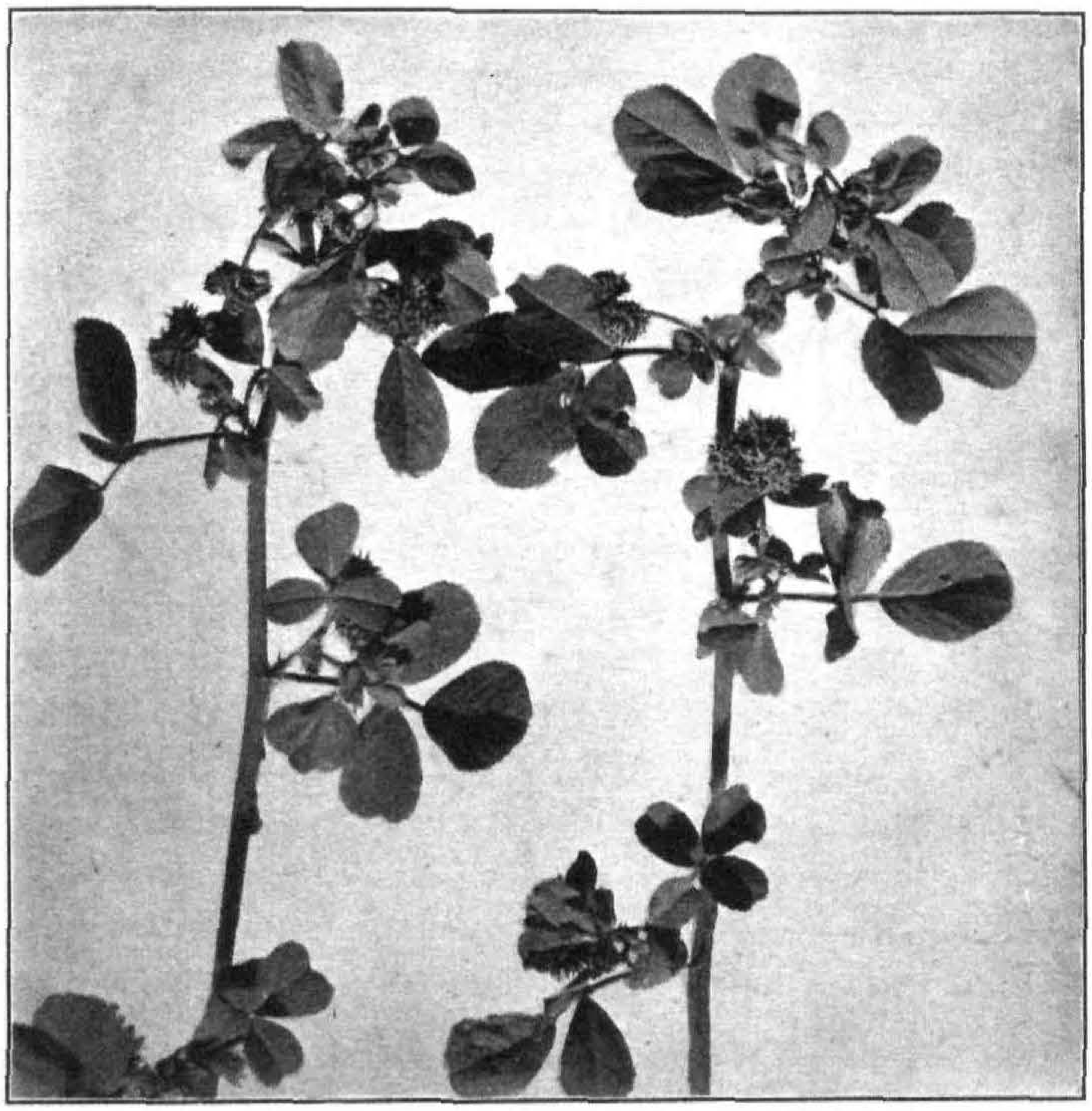


FIG. 190.—Tooth bur clover (Medicago hispida).

California. It finds some use as a pasture, hay, cover and green-manure crop.

In addition to the two species of bur clover given above, there are about 35 species that are not cultivated to any extent. They are all native to the Mediterranean region. All are warm-climate crops.

MELILOTUS (Sweet Clover)

Generic Description.—Sweet clovers are tall, erect, annual or biennial herbs, with a fragrant odor, especially when bruised. The *leaves* (Fig. 183, B) are pinnately three-foliate, petioled, and possess large stipules and dentate leaflets, the

FIG. 191.—Leaves and inflorescence of white sweet clover (Melilotus alba) on left, and alfalfa (Medicago sativa) on right.

veins of which end in the teeth. The *flowers* are long, slender, and in one-sided, axillary racemes. They are small, and white or yellow. The calyx teeth are short and about equal. The standard is obovate or oblong, the wings oblong, and the keel short and obtuse. The stamens are diadelphous (nine and one). The sessile or stalked ovary bears a single

thread-like style. The *pods* are ovoid or globose, small, indehiscent or finally 2-valved, and usually one-seeded. Ordinarily, all the seeds of one year's production do not germinate the first season. This results from the production of some "hard seeds."

There are 15 to 20 species of sweet clover, natives of Europe, Africa, and Asia. They are known by different names, such as wild alfalfa, melilot, giant clover, Bokhara, and sweet clover.

The young plants resemble alfalfa, from which they can be distinguished by the bitter taste of the foliage and the thicker leaflets.

Species of Melilotus.—There are two common species of *Melilotus: M. alba*, white sweet clover, and M. *officinalis*, yellow sweet clover. Several other species of *Melilotus* have been used agriculturally to some extent; among such are *M. indica* ("sour clover"), *M. altissima*, *M. gracilis*, and *M. speciosa*.

The characters of the two most important species are arranged in parallel rows for purposes of comparison.

M. alba	*M. officinalis*
Commonly biennial.	Commonly annual, sometimes biennial.
Flowers white.	Flowers yellow.
Standard slightly longer than wings.	Standard about equal the wings.
Pods ovoid, glabrous.	Pods ovoid, often slightly pubescent.

MELILOTUS ALBA (White Sweet Clover)

Description.—This is an erect and smooth-stemed plant which is usually biennial in its habit. An annual variety of white sweet clover has been found in the South. The ordinary biennial form may reach a height of 3 or 4 feet the first season, from seed; the second season's growth is much more vigorous, and will yield two crops in the Northern, and three in the

Southern States. New sprouts arise from above ground near the base of the plant after each cutting, and for this reason the plants must not be cut too close to the ground line. The *leaves* have thick, oblong, finely toothed leaflets which are narrowed at the base, and truncate, notched or rounded at the apex. The *racemes* are numerous, slender, and often one-sided. The *flowers* are white and have a standard which is somewhat longer than the wings. The *pods* are ovoid, slightly reticulated (netted), and smooth.

The species is a native of Eurasia. It is a common roadside and waste-place weed throughout this country.

MELILOTUS OFFICINALIS (Yellow Sweet Clover)

Description.—This plant is much like the preceding. It does not grow so tall, however, is less common, and has yellow flowers. It blooms somewhat earlier than the white sweet clover and is more commonly annual in its habit than biennial. It is a native of Eurasia and, like the preceding species, has become naturalized in this country, being widely distributed as a ruderal throughout both the Northern and Southern States.

Environmental Relations.—The sweet clovers thrive in both semi-arid and humid climates, and upon all types of soils—heavy and light, rich and poor, well-drained and illy-drained. They are also drought-resistant. It is being introduced where, for any reason, alfalfa and clover have failed.

Uses of Sweet Clovers.—Like other legumes, sweet clover supports nodules of bacteria on its roots. In fact, it is nearly as valuable as alfalfa to plow under as a green manure to renew the soil. It makes good hay when properly handled, and for pasturage purposes it has considerable value. As a forage crop, it can be utilized where alfalfa or red clover cannot be grown successfully. The plant becomes coarse and unpalatable soon after blooming, and

hence it must be cut before this stage. The plants possess a bitter principle, cumarin, which may cause an animal to reject them as food at first, but usually the animal becomes accustomed to them.

White sweet clover is much larger and more vigorous than yellow, and consequently is usually the one recommended for cultivation.

SOJA (Soy Bean)

Generic Description.—The soy beans are prostrate or erect herbs with pinnately three-, rarely five- or seven-, foliate *leaves*. The *flowers* are in short axillary racemes, and are purple or whitish. The *pods* are linear or falcate, and two-valved. The *seeds* are globular and pea-like.

There are between 15 and 20 species of *Soja*, natives of tropical Asia, Africa, and Australia. There is only one species of any economic importance. This is *Soja max*.

SOJA MAX (Soy Bean, Soja Bean, Coffee Bean)

Description.—This is an erect, bushy appearing, hairy annual, varying from 1½ to 6 feet in height (Fig. 192). Unlike the cowpea, it has a definite growth, that is, reaches a certain size and matures its seed. All the pods of the soy bean mature at one time. In the cowpea, new pods are formed as long as the plant lives. The *tap root* is short and strong. The *leaves* are trifoliate. Usually they have withered and fallen by the time the pods are mature, but in some varieties remain green and stay on the plant for sometime after the pods mature. The *flowers* are borne in axillary clusters; they are small, and either white or purple in color. The flowers are self-pollinated as a rule, and are completely self-fertile. Occasional cross-fertilization occurs in the field when varieties are planted very close together. The *pods* are from 1 to

$2\frac{1}{2}$ inches long, yellowish or brown, and covered with short bristly hairs. As many as 300 to 400 pods have been found on one plant, and each pod usually contains two or three seeds. In fact, the soy bean is the greatest seed producer of any legume grown in temperate climates. The seeds vary greatly in color; there are shades of cream, white, yellow, green, brown, and black; they also vary in shape from globose to elliptical. Under the most favorable conditions, soy bean seeds do not retain their viability for more than five or six years.

FIG. 192.—Soy bean (Soja max). (*After Piper.*)

Soja max is a native of China and Japan. The cultivated varieties are adapted to the warmer sections of the United States; they are intolerant of cool nights. However, there are several very early maturing varieties which may be grown in the northern tier of States. The soy bean will grow in moist climates, and also manifests drought-resistant propensities. The plant is grown on a variety of soil types, and will even produce a fair crop on poor soils of a sandy nature.

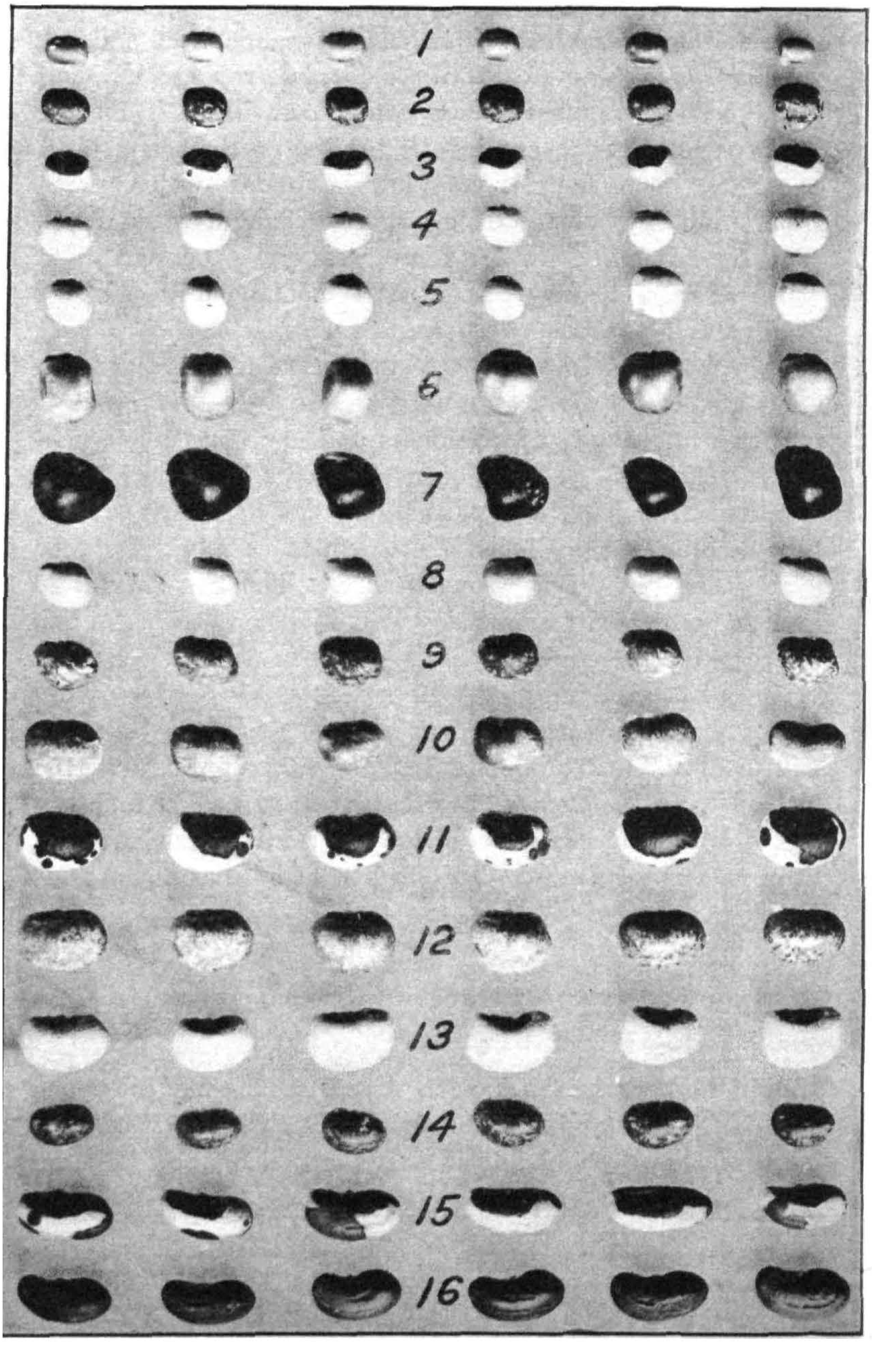
Uses.—The soy bean is the most important legume in Asiatic countries, and is becoming of increasing value in the United States. The chief product of the bean is the oil which is expressed from the seeds. It is used in the manufacture of soaps, lubricants, water-proof goods, linoleum, rubber substitutes and printing ink; also in the preparation of varnishes and paints, as a substitute for linseed oil. After

the oil is expressed from the seed, the "cake," either unground or ground into a meal, is used as stock feed or as a fertilizer. Soy-bean meal is of considerable value as human food. Soy-bean flour is an important constituent in many food specialties such as diabetic breads, crackers and biscuits. Soy-bean flour is very low in carbohydrates, that made from soy-bean cake having a carbohydrate content of 33.85 per cent.,[1] as compared with 75.35 per cent. in wheat flour. The protein content of flour made from soy-bean cake is given as 47.3 per cent., whereas that of wheat flour is but 11 per cent. Soy beans are also utilized to make a so-called soy-bean milk, which is valued for cooking purposes by bakers, confectioners and chocolate manufacturers. The seeds of soy beans are sometimes used as a substitute for coffee. Soy-bean hay has a comparatively high feeding value. It is recommended as a pasture for hogs. The plant is recognized as a valuable soiling and ensilage crop. Nitrogen-fixing bacterial nodules occur on the roots of the soy bean. The soy bean is used in the South primarily as a soil improver. In some sections it has practically replaced cow peas. A ton of soy beans, 33⅓ bushels, will yield about 240 pounds of oil and 1,620 pounds of meal. The oil brings about the same price as cotton seed oil, and the meal, on account of its higher protein content, brings more than cotton seed meal. The meal is utilized as a feed and fertilizer.

VIGNA (Cowpea and Related Species)

Description.—The "Vignas" are usually climbing or trailing herbs, sometimes erect, that are much like the common bean. They differ from the common bean (*Phaseolus vulgaris*), however, mainly in that the keel of the corolla is

[1] Data from the U. S. Dept. of Agri. Bureau of Chemistry.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short and merely incurved rather than spirally coiled. The *leaves* are pinnately trifoliate. The *flowers* are yellowish or purplish, in head-shaped or racemose inflorescences at the ends of long peduncles; these arise in the axils of leaves. The *calyx* is five-toothed. The *stamens* are diadelphous (nine and one). The *ovary* is sessile, many-ovuled, and bears a style that is bearded along the inner side. The

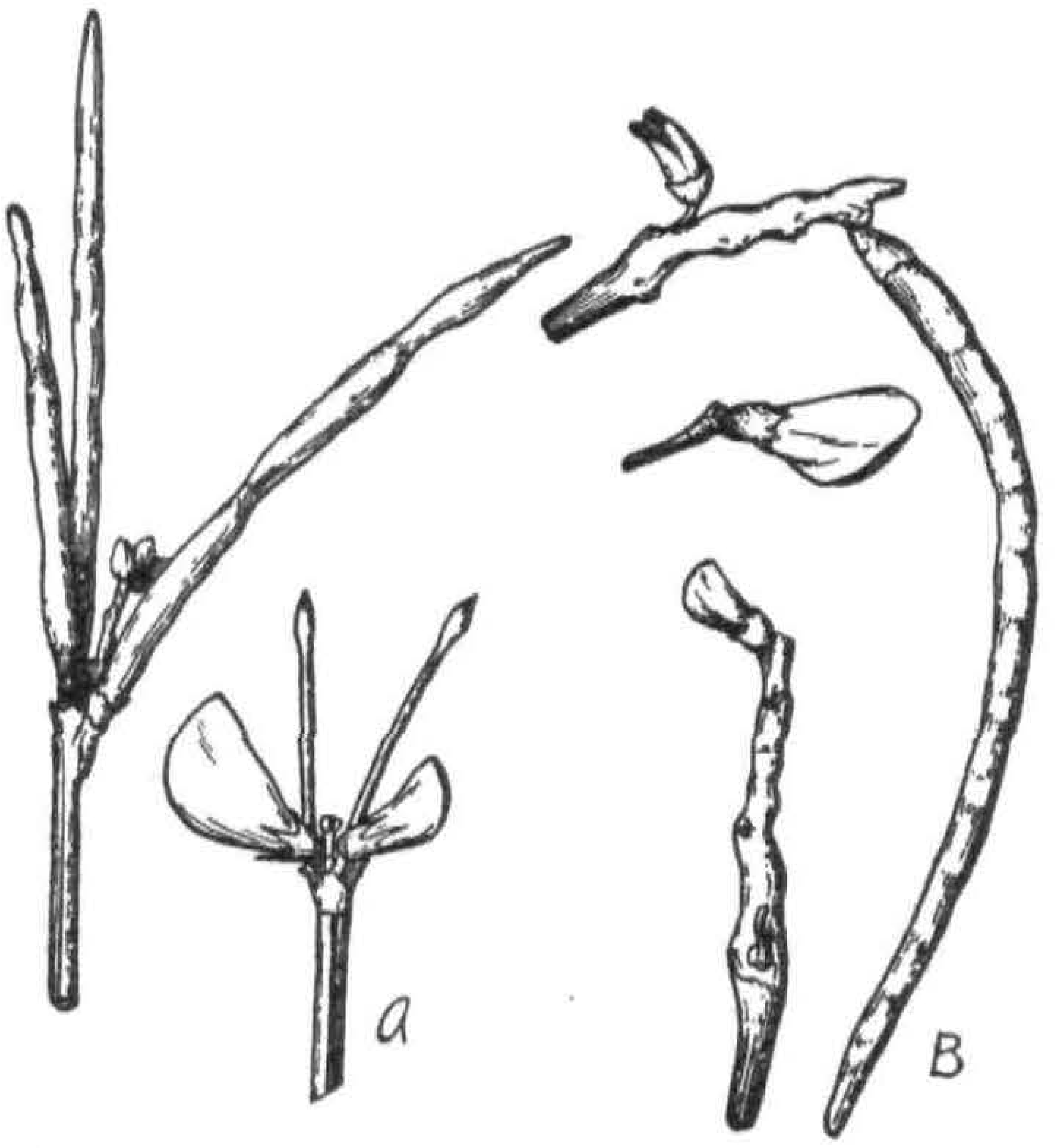


FIG. 194.—*A*, flowers and fruit of catjang (Vigna catjang); *B*, flowers and fruit of cowpea (Vigna sinensis). (*After U. S. Dept. of Agri.*)

pods are linear, straight or slightly curved, and two-valved. The *seeds* are much like the common kidney bean in shape (Fig. 193).

All the *Vigna* spp. ("Vignas") are natives of warm and tropical regions, and consequently they have been most successfully cultivated in the Southern States.

FIG. 193.—Seeds of 16 varieties of Vigna showing range in variation of shape, size and color. The top three rows are catjangs (Vigna catjang), the bottom two rows are asparagus beans (Vigna sesquipedalis), and the others are cowpeas (Vigna sinensis). (*After Piper, U. S. Dept. of Agri.*)

Species.—There are but three cultivated species of "Vignas:" *Vigna sesquipedalis* (asparagus bean), *Vigna catjang* (catjang), and *Vigna sinensis* (cowpea). The asparagus bean has pendant pods 1 to 3 feet long, and kidney-shaped seeds 8 to 12 millimeters long. In catjang, the pods are small, 3 to 5 inches long, and usually erect or ascending (Fig. 194). In the cowpea, the pods are 8 to 12 inches long, and become pendant with age. The cowpea is by far the most important, economically.

VIGNA SINENSIS (Cowpea)

Description.—The cowpea is a vigorous annual herb with a strong tap root which sends out large side roots almost horizontally for 1 or 2 feet (Fig. 195). The greater part of the root system lies in the first 1½ feet of soil. The varieties vary in habit from prostrate trailing herbs to tall and half-bushy forms. The cowpea has an indeterminate growth, that is, it continues to grow indefinitely, providing environmental conditions are favorable. As in the majority of plants vegetative growth is favored by an abundance of water and heat, and seed production is stimulated by adverse conditions. The first pods may come to maturity within seventy to ninety days in the so-called early varieties; on the other hand, some varieties do not even come into bloom under conditions prevailing in the states along the Gulf of Mexico.

The *flowers* are white or pale violet with three bracts at the base of each pedicel. The cowpea flower is capable of self-fertilization, and this is probably the most common occurrence although the flowers are often visited by honey bees or bumblebees. They are attracted chiefly by the extra floral nectaries. The long *pods* (Fig. 194) are cylindrical, somewhat curved, and usually constricted between the seeds. The *seeds* are numerous, usually bean-shaped, spotted, marbled, speckled, or marbled and speckled, and have a

dark circle around the white hilum. Great variation occurs in pods and seeds. There are two groups of cowpeas based upon pod and seed characteristics; *kidney* and *crowder*. The former have compressed pods with kidney-shaped seeds; the latter have thick-walled, cylindrical pods with globular seeds.

FIG. 195.—Cowpea (Vigna sinensis). (*After Piper.*)

Environmental Relations.—The cowpea is of tropical origin, and, hence, is adapted to those sections of the country with warm summers; in fact, it requires more heat than corn, and like corn, does not thrive where the nights are cool. It is seldom grown north of the Ohio River. It will grow on many different soil types, and will withstand shading.

Uses.—The cowpea is of very great economic importance. It is the chief forage plant in the South Central and South Atlantic States. The acreage of the crop is increasing each year. Cowpea hay is prized as food for stock. The plant may also be pastured with hogs or sheep when mature, or with cattle before the peas mature. The plant is being introduced into many localities as a catch crop or as a green manure, and is adapted to rotation in a cropping system. The seeds are fed to poultry, and are also recommended as

a food for man. The roasted seeds are a substitute for coffee.

STIZOLOBIUM (Velvet Bean)

Generic Description.—The velvet beans are strong, annual twining herbs, with fleshy surface roots, and stems, which, in some species, may attain a length of 50 feet or more. The *leaves* are trifoliate, petiolate, and with small stipules, and bristle-like structures in the axils of leaflets. The *flowers* are borne singly or in twos or threes, and vary in color from white to dark purple; they measure 1 to 1½ inches long. The *pods* vary in length for 2 to 3 inches in some varieties to 5 to 6 inches in others; they are covered with black, velvety hairs in *Stizolobium deeringianum*, including the Florida and Alabama varieties, and with white or grayish hairs in *S. hasjoo* (Yokohama Velvet bean) and *S. niveum* (Lyon Velvet bean). The pods are also covered with short bristles which irritate the skin. The *seeds* are large, globular to oblong, and white or marbled, brown or black.

There are approximately a dozen species of this genus, which are natives of the tropics of the Old World. Several species, *S. deeringianum*, *S. hasjoo* and *S. niveum*, have been introduced into the Southern States and to as far north as Virginia and Tennessee, where they are now being grown extensively, as a grazing crop for cattle and hogs, as a green manure crop, and to a less extent as a smothering crop.

Most of the varieties now grown are creeping and make a rank growth, among which are such varieties as Florida, Georgia, Alabama and Lyon. Yokohama is a variety with a much smaller vine than the preceding. Bush velvet bean is a non-twining variety, a mutation from the Florida.

ARACHIS HYPOGÆA (Peanut, Goober)

Root, Stem.—The peanut is an annual plant with a tap root (Fig. 196). The plant may be low and prostrate, as in the "running types," or upright and bushy, as in the "bush types." The *stems* are thick, angular, branching, and hairy.

FIG. 196.—Peanut (Arachis hypogæa). (*After Jones.*)

Leaves.—The leaves are pinnately compound, usually with two pairs of subsessile, entire leaflets, and no tendrils; the elongated stipules are adnate to the petiole base.

Flowers (Fig. 197).—The flowers are axillary, sessile, and orange-yellow in color. There are two sorts of flowers on the plant, sterile and fertile. Sterile flowers are most numerous in the upper axils, on long, slender pedicels; they have monadelphous stamens (nine united, one abortive) and a minute abortive ovary. The calyx tube is long and slender, and bears on its rim the calyx lobes, corolla, and stamens; the four superior lobes of the calyx are united, while the inferior one is free. The standard is suborbicular,

the wings oblong and free, and the keel incurved. The *ovary*, at the base of the long, narrow calyx tube, has one to several ovules, and bears a long thread-like style, terminated by a very small stigma.

Development of Fruit (Fig. 196).—After the ovules are fertilized, the stamens and corolla fall off; then the flower stalk elongates, bends downward, and carries the developing ovary several inches into the ground. Once buried, the ovary ripens. If the ovary is not brought underground, it withers, and fails to mature.

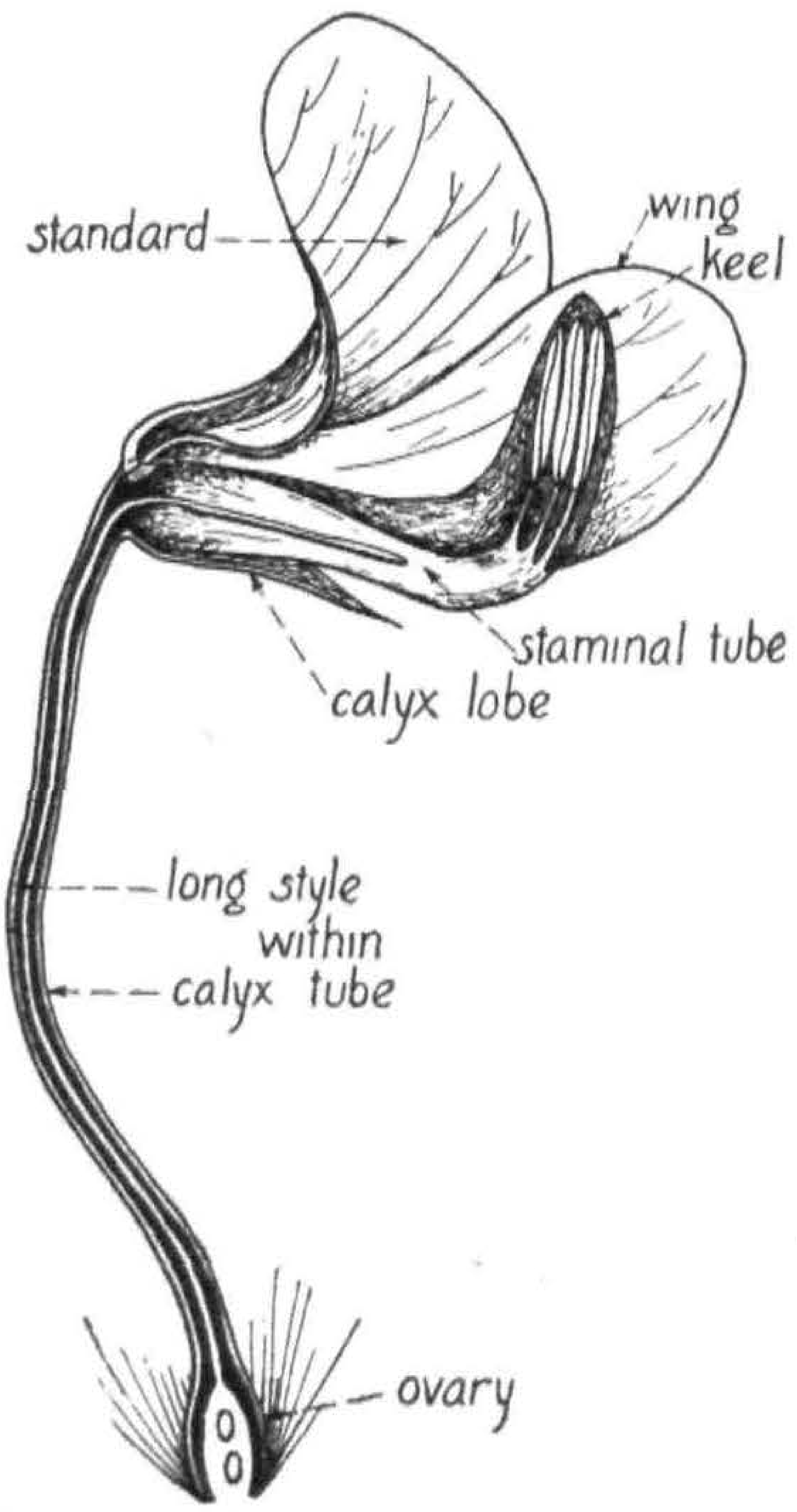


FIG. 197.—Flower of peanut (Arachis hypogæa). (*After Tanbert.*)

Fruit.—The fruit is a large, oblong, reticulated, indehiscent legume, with one to several ovoid seeds. The "shell" of the "peanut" is the pericarp; the thin skin that surrounds each seed or pea ("nut") is the testa. The cotyledons are large, and rich in stored food.

Types.—The American varieties may be divided into two large groups: (1) *large-podded* and (2) *small-podded*. Each of these is further subdivided into "bush" or "bunch," and "running" types. Well-known varieties in this country are Virginia Bunch, Virginia Runner, Carolina, Spanish, and Tennessee Red. The last-named variety has red-skinned seeds. The nuts in the Spanish variety are smaller than those of the other

types. Large-podded varieties are sometimes termed "*Jumbos*."

Environmental Relations.—The peanut is a tropical plant. Consequently, it is raised where the growing season is long, and warm. It succeeds best south of the 36° latitude.

The plant is favored by ample sunshine and moderate rainfall. It is grown successfully on both sandy and clay soils, although the former are preferred, especially when the pods are grown for the market and a bright, clean appearance is desired.

Uses.—Peanuts are largely used in the roasted state as a human food. Peanut butter has become a very popular food article. One bushel of first-class nuts will yield about 12 pounds of butter. Oil, salted peanuts and peanut candies are other products. The nuts ("goobers") are fed to hogs, or the animals are turned in to pasture on both the vines and nuts. *Peanut oil*, pressed from the seeds, is a nearly colorless product, which is employed as a salad oil, to a limited extent in the manufacture of soap, and in the making of oleomargarines and similar compounds. Analyses show that Spanish and Valencia peanuts are richer in oil than Virginia and other common types. The percentage of oil in shelled nuts varies from about 45 to 50 per cent. Peanut meal, the product left after pressing the oil from the seeds, is a high-grade stock feed. Nearly all peanut oil used in this country is made in Europe. The United States imported 1,332,108 gallons of the oil during 1914.

LESS IMPORTANT LEGUMES

The following list includes several of the less important members, agriculturally, of the Pea Family.

Lupinus (Lupines).—Annual or perennial herbs with palmately seven- to fifteen- foliate leaves, and spikes of white, yellow, or blue, showy flowers. They can grow on poor sandy soil, but are little used in this country except

to plow under as a green manure. The species used for this purpose are annuals.

Lespedeza striata (**Japan Clover**).—A branched, spreading annual with three-foliate leaves, short petioles, and small flowers in the axils of the leaves.

FIG. 198.—Chick pea (Cicer arietinum).

It was introduced from Japan or China to the South Atlantic States, where it is quite largely grown for pasture and hay. It is adapted to clay soils and does well on thin uplands.

Onobrychis viciæfolia (**Sainfoin**).—A deep-rooted perennial with erect stems, odd-pinnate leaves, six to twelve leaflets, and erect, dense racemes of

rose-colored flowers. The one-seeded, brown, lens-shaped pods are indehiscent. The seed loses its viability rapidly, and is slow to germinate.

The plant was early introduced into America from Asia, but it is little grown here. It is adapted to dry barren lands that are not suited to clovers and alfalfas. It has been grown with success on calcareous soils.

Ornithopus sativus (Serradella).—A low, branched annual, with pinnately compound leaves, and rose-colored or purplish flowers in umbels. The pods break into joints. The plant makes good hay and thrives on fairly thin soils, if not dry. It grows best in cool weather, and is not very hardy.

Lotus corniculatus (Birds-foot Trefoil).—An annual plant similar to clover. The low-spreading stems are from a long tap root; bright yellow or red flowers occur in small clusters at the ends of the stems; pods are narrow and pendant. It is an Old World plant, but is naturalized in the South where it is sown in mixtures for dry pastures.

Cicer arietinum (Chick-pea).—A bushy, hairy annual, 1 to 2 feet high, with odd-pinnate leaves and small, white or pink, solitary flowers followed by short, thin pods. The seeds are pea-like, with a beak-like projection near the hilum. The plant is grown in Europe, Asia, and Mexico for its seeds which are used for both stock and human food. The herbage is unfit for stock because of a poisonous principle. The seeds have been used as a coffee substitute.

Trigonella fœnum-grœcum (Fenugreek).—An erect plant with clover, like leaves, and long, pointed pods. It is grown principally for its seeds, which have medicinal properties, and also as an orchard green manure. The seeds are made into a "condition powder" for horses.

References

Bartlett, G.: The Native and Cultivated Vicieæ and Phaseoleæ of Ohio. Ohio Nat., 15: 393–404, 1914.

Beal, A. C.: Evolution and Pollination of the Sweet Pea. Florists' Exch., 32: 140–141, 1911.

Beattie, W. R.: Peanuts. U. S. Dept. Agr. Farmers' Bull. 356: 1–40, 1909. The Peanut. U. S. Dept. Agr. Farmers' Bull. 431: 1–39, 1911.

Blinn, Philo: Alfalfa—the Relation of Type to Hardiness. Colo. Agr. Exp. Sta. Bull. 181: 1–16, 1911.

French, G. T.: Observations on Medicago lupulina L. Science, n. s., 2 28: 127, 1908.

Fucsko, Mihaly: Über die biologischen und entwickelungsgeschichtlichen Verhaltnisse des Pericarps der Papilionaten. Ung. Bot. Bl., 8: 264–265, 1909.

Anatomie, Entwickelung und Biologie der Fruchtwand der Papilionatæ-Bot. Közlem, 8: 154–212, 1909.

GREGORY, R. P.: The Seed Characters of Pisum sativum. New Phytol., 2: 226–228, 1903.

HANDY, R. B.: Peanuts: Culture and Uses. U. S. Dept. Agr. Farmers' Bull. 25: 1–23, 1896.

HEADDEN, WM. P.: Alfalfa. Colo. Agr. Exp. Sta. Bull. 35: 1–92, 1896.

JARVIS, C. D.: American Varieties of Beans. Cornell Agr. Exp. Sta. Bull. 260: 149–255, 1908.

JONES, B. W.: The Peanut Plant. Orange Judd Co., 1885.

KIRCHNER, OSKAR: Über die Wirkung der Selbstbestäubung bei den Papilionaceen. Naturw. Ztschr. Land-u. Forstw. Jahrg., 3, Heft 1: 1–16, 1905.

MARTIN, J. N.: Relation of Moisture to Seed Production in Alfalfa. Iowa Agr. Exp. Sta. Research Bull. 23: 303–324, 1915.

MCKEE, ROLAND, and RICKER, P. L.: Non-perennial Medicagos: the Agronomic Value and Botanical Relationship of the Species. U. S. Dept. Agr. Bur. Plant Ind. Bull. 267: 1–36, 1913.

OAKLEY, R. A., and GARVER, SAMUEL: Medico falcata, a Yellow-flowered Alfalfa. U. S., Dept. Agr. Bull. 428: 1–70, 1917.

PAMMEL, EDNA C., and CLARK, CLARISSA: Studies in Variation of Red Clover. Proc. Ia. Acad. Sci , 18: 47–53, 1911.

PAMMEL, L. H., and KING, CHARLOTTE M.: Pollination of Clover. Proc. Ia. Acad. Sci., 18: 35–45, 1911.

Pollination of Clover. Contrib. Bot. Dept. Ia. State College, 47: 1–45, 1911.

PFENNINGER, URS.: Untersuchung der Fruchte von Phaseolus vulgaris L. in versichiedenen Entwickelungstadien. Ber. Deut. Bot. Ges., 27: 227–234, 1909.

PIPER, C. V., and MORSE, W. J.: The Soybean; History, Varieties, and Field Studies. U. S. Dept. Agr. Bur. Plant Ind. Bull. 197: 1–84, 1910.

Five Oriental Species of Beans. U. S. Dept. Agr. Bull. 119: 1–32, 1914.

The Bonavist, Lablab, or Hyacinth Bean. U. S. Dept. Agr. Bull. 318: 1–15, 1915.

The Soy Bean, with Special Reference to Its Utilization for Oil, Cake and Other Products. U. S. Dept. Agr. Bull. 439: 1–20, 1916.

PIPER, C. V.: Agricultural Varieties of the Cowpea and Immediately Related Species. U. S. Dept. Agr. Bur. Plant Ind. Bull. 229: 1–160, 1912.

Soja Max. Jour. Am. Soc. Agron., 6: 75–84, 1914.

PIPER, C. V., EVANS, MORGAN W., MCKEE, ROLAND, and MORSE, W. J.: Alfalfa Seed Production; Pollination Studies. U. S. Dept. Agr. Bull. 75: 1–32, 1914.

PIPER, C. V., and MCKEE, ROLAND: Vetches. U. S. Dept. Agr. Farmers' Bull. 515: 1–28, 1912.

SCOFIELD, CARL S.: The Botanical History and Classification of Alfalfa U. S. Dept. Agr. Bur. Plant Ind. Bull. 131: 11–19, 1908.

SHAW, THOMAS: Canadian Field Peas. U. S. Dept. Agr. Farmers' Bull. 224: 1–16, 1905.

TRACY, W. W.: American Varieties of Garden Beans. U. S. Dept. Agr. Bur. Plant Ind. Bull. 109: 1–173, 1907.

WESTGATE, J. M.: Variegated Alfalfa. U. S. Dept. Agr. Bur. Plant Ind. Bull. 169: 1–63, 1910.

WESTGATE, J. M., and HILLMAN, F. H.: Red Clover. U. S. Dept. Agr. Farmers' Bull. 455: 1–48, 1911.

WESTGATE, J. M., and VINALL, H. N.: Sweet Clover. U. S. Dept. Agr. Farmers' Bull. 485: 7–39, 1912.

WESTGATE, J. M., COE, H. S., WIANCKO, A. T., ROBBINS, F. E., HUGHES, H. D., PAMMEL, L. H., and MARTIN, J. N.: Red-clover Seed Production: Pollination Studies. U. S. Dept. Agr. Bull. 289: 1–31, 1915.

WIGHT, W. F.: The History of the Cowpea (Vigna unguiculata) and Its Introduction into America. U. S. Dept. Agr. Bur. Plant Ind. Bull. 102: 43–59, 1907.

WINTON, KATE, B.: Comparative Histology of Alfalfa and Clovers. Bot. Gaz., 57: 53–63, 1914.

WOODWORTH, C. M.: The Extent of Natural Cross-pollination in Soy beans. Jour. Amer. Soc. Agron., 14: 278–283, 1922.

CHAPTER XXX

LINACEÆ (Flax Family)

Stem, Leaf.—The species of this family are annual or perennial herbs, or shrubs. The plants are tap-rooted, and each *tap root* bears a number of slender, lateral branches. The *stems* are single. The *leaves* are simple, narrow, nearly sessile, and usually alternate, although sometimes opposite (*L. catharticum*). They are linear, linear-lanceolate, or oblong, and sharply awn-pointed, blunt, or rounded at the apex.

Inflorescence and Flowers.—The inflorescence may be a few-flowered corymb or cyme, or the flowers may be more or less scattered on the branches. The *flowers* (Fig. 21) are perfect, regular, and five-parted in all respects. The *sepals* are imbricated and persistent. The *petals* are wedge-shaped, and may be as long or longer than the sepals. They may be some shade of yellow or blue, orange with rose-tinted base, red, or white. The five *stamens* have their filaments united at the base. The outer whorl of stamens is wanting or staminodial. The *pistil* consists of a five-celled ovary, each cell of which bears two ovules. The five styles may be free, united to the stigmas, or united part way from the base.

Fruit.—The flax fruit is a five-celled capsule with two seeds in each cell; each cell is partially or completely divided into two by a false partition between the two seeds, thus making the capsule apparently ten-celled (Fig. 22).

The Names Derived from "Linum."—This family contains but one important genus, *Linum*. The names *Linum*

is the latin for flax. The word "linen" means made from flax or of flax. It is from these and other similar foreign names that we get our common words linen, lint, linseed, and line.

Geographical, and Environmental Relations.—The family has about 135 species, which are widely distributed over the world. The important commercial species is *L. usitatissimum*. All cultivated flax varieties in this country are treated as belonging to this one species.

Flax is raised under a wide variety of climatic conditions and soils. In regions with low rainfall, the crop is of little value for fiber, and hence is grown chiefly for its seed. A fair quality of fiber flax is produced in certain sections of the United States where the rainfall is 25 to 30 inches. The water requirement of flax is higher than that of any of the cereals, being about three times that of millet and sorghum.

LINUM USITATISSIMUM (Common Flax)

Habit, Root.—Common flax is an upright herb which under cultivation grows to a height of from 1 to 4 feet (Fig. 199).

It is a dainty surface feeder with a small root system; this consists of a slender tap root sparingly supplied with slender branches in the first 12 to 18 inches of soil. The tap root runs downward vertically to a depth of 3 to 4 feet in some cases. No network of roots is formed near the surface of the soil. Long-stemmed flax as compared with other varieties appears to have a weaker root system and less root penetration. Deep planting is adverse to root development of flax.

Stem.—The stem is simple, erect, and branching in the upper part, rarely at the base. As it matures, it becomes rigid, at the same time retaining considerable elasticity due to the bast fibers.

Flax Fibers.—Three tissue areas are recognizable in the stem: pith, wood, and bark. The flax bark contains the bast or flax fiber cells. These bast fibers give flax straw its great financial value since they make up the part from which linen is made. Each bast fiber is a single cell, 25 to 30 millimeters long, and cylindrical in shape.

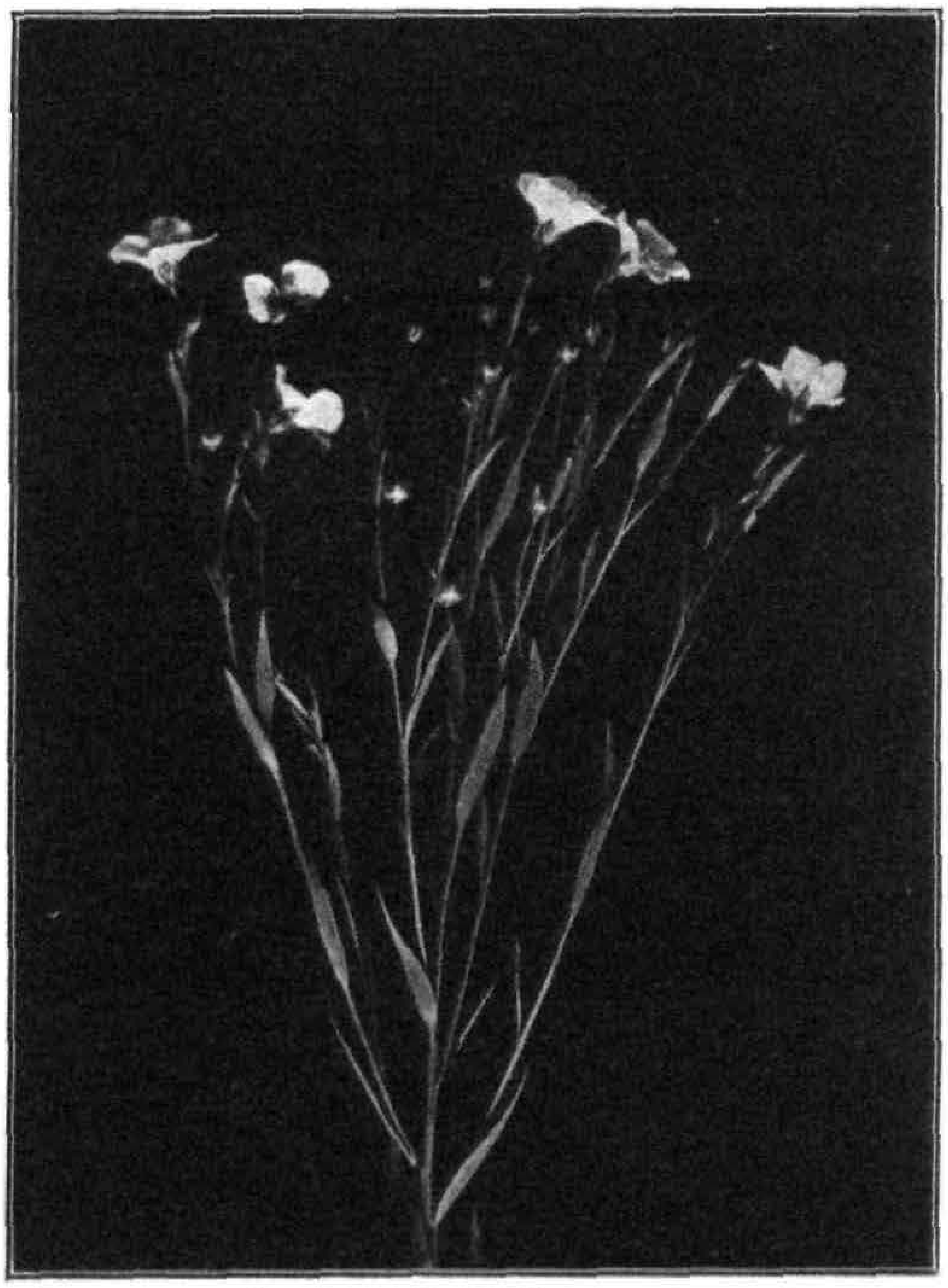


FIG. 199.—Common flax (Linum usitatissimum).

Leaves, Inflorescence and Flowers.—The leaves are narrow, entire, and blunt at the apex. The inflorescence is loosely cymose. The flowers vary in color from white to deep blue. The same plant always bears flowers of the same color. Yellow-flowered varieties are not found in this species. The petals are large, conspicuous, wedge-

shaped, and about twice as long as the sepals. A nectar gland occurs at the base of each filament.

Pollination.—It appears that flax is normally self-pollinated. Individual flowers produce seed freely whether associated with other flowers or not, and there is no or little evidence of natural crossing between distinct varieties even when planted in close proximity. The flowers open usually in early morning, and close toward noon. When the flower closes, the stamens are caused to bend inward and come in contact with the stigma, upon which the pollen is dusted, and self-pollination results.

Mature Fruit—The flax fruit (Fig. 22) is a round capsule known commercially as the "seed ball." The seed ball is composed of five fused carpels. The balls are divided into five true cavities or locules by means of five true partitions (septi) extending from the wall (pericarp) to the axis. Each locule contains two seeds and is divided more or less incompletely into two loculi by means of false septa. The seed balls are 1/4 inch or more in diameter. When fully ripe, they are easily separated into parts at the points where the carpels are joined.

Seeds.—The seeds vary in length from 1/7 to 1/5 inch. They are lenticular, compressed, and slightly longer than wide. They have a very smooth, polished surface and vary in color from yellow to dark brown. Light brown is the standard color. A mucilaginous material which quickly becomes sticky (viscid) in hot water is found filling the epidermal cells of the seed. It is this substance which gives flax its medicinal value. The embryo is surrounded by a thin layer of endosperm which, in the mature seed, contains starch.

History and Geographical.—Common flax is a native of Europe. It is now widely distributed over the world, being grown commercially in many countries. India is a heavy producer of seed, and in Argentina it is grown

extensively for oil. Common flax has been in cultivation from the earliest times. It is known, for example, that the cloth used for wrapping Egyptian mummies was made of flax fiber. There is written record that the plant was used by the Greeks in the seventh century before Christ, and the early Romans regarded it worthy of cultivation. The Greeks and Romans employed the seed as food.

Types and Varieties.—There are large-seeded and small-seeded varieties. The large-seeded types are sometimes known as Sicilian flax, and are grown almost entirely for their seed, rather than fiber; there are both blue- and white-flowered sorts. The small-seeded types are grown both for fiber and seed; there are both blue- and white-flowered varieties. The fiber flaxes have more slender stems, fewer basal branches, and a more compact panicle than the seed flaxes.

Uses.—*Linseed Oil.*—The manufacture of linseed oil is carried on in manufacturing plants having investments of millions of dollars. The seeds are crushed, heated to about 165°F., placed in tanks or cylinders, and while hot, treated with naphtha to extract the oil. From 30 to 39 per cent. of the seed is oil. Linseed oil is used in the manufacture of paints, patent leather and varnishes. *Linoleum* is a preparation of linseed oil which is hardened by treating with sulphur chloride or by exposure to heated air. It is sometimes used as a substitute for india-rubber. Oil cloth and other sorts of floor cloth, are made by mixing ground cork with the hardened linseed oil (linoleum), and pressing upon canvas.

Oil Cake and Oil Meal.—The residue from the crushed flax seeds is known as oil cake. It is sold either as oil cake or ground into a meal, and used as a stock food. Belgium and Holland are our chief customers for linseed-oil cake.

Flax Fiber.—Linen is made from flax fiber. Our finest linens are from foreign grown flax, the best of which is grown in Belgium in a region through which flows the River Lys. The creamy Flemish flax from which the finest linen fabrics

are made is grown in this section. Flax fiber is also utilized for making thread, carpet yarns, fishing lines, seine twines, etc. The threshed straw of the northwestern seed flax is also employed to some extent for upholstering, for insulating cold-storage plants, refrigerator cars and ice boxes. A fine grade of paper (linen paper) is made from linen rags. Linen paper treated with sulphuric acid gives a parchment which takes the place of "sheep skin."

Preparation of Flax Fiber.—Flax plants for fiber are pulled by hand and tied into small bundles. The bundles are shocked and permitted to cure. After the seed is thrashed from the plants, they are spread out thinly on the ground and exposed to the weather for several weeks. The exposure brings about a partial separation of the bark and wood. This process is known as retting. It is essentially a fermentation process. Retting is also carried on in stagnant water and fresh running water. Most French and Belgium flax is retted in running streams, while most Irish flax is retted in stagnant water. The bundles of straw are then pounded by hand or bent by machinery, until the fiber is almost entirely freed of other stem parts. The next treatment, known as "scutching," consists in beating the fibers until any fragments of bark or wood or course fibers, not removed in the breaking process, are eliminated. Paddles, operated by hand or by machinery, are used in the scutching process. The fibers are sorted and baled, and kept in this form until ready to be spun.

Production of Flax.—Most of the flax for fiber is grown in the European countries. The United States is one of the largest seed-producing countries but raises a very small amount of fiber. In 1914, Argentina produced 39,171,000 bushels of flax seed, British India 15,440,000 bushels, and United States 13,749,000 bushels. The large flax seed-producing States in 1919 were North Dakota, Minnesota, South Dakota, Montana and Kansas.

CHAPTER XXXI

RUTACEÆ (Rue Family)

Description.—This family is represented by trees, shrubs, and herbs. The *leaves* are alternate or opposite, simple or compound, exstipulate, and glandular-dotted. The glands, which appear as translucent dots, are internal. They vary somewhat in size and shape. The *flowers* (Figs. 200 and 201) are solitary or in small axillary or terminal cymes. The *sepals* are four to five in number, but sometimes absent. There are as many *petals* as sepals, and they are either hypogynous or perigynous. The separate or united *stamens* are attached to the receptacle, and vary considerably in number; the anthers are two-celled, usually versatile, and introrsely dehiscent. The two to five *carpels* may be distinct, or united to form a compound pistil. The receptacle is frequently modified to form an annular disk (Fig. 201, B). The *fruit* is a capsule, berry, drupe, or samara. The seeds are oblong or kidney-shaped, and have a straight or curved embryo, a fleshy endosperm, and fleshy cotyledons. The seeds of lemon may germinate in the fruits.

FIG. 200.—Floral diagram of Citrus. (*After Eichler.*)

Geographical.—The family is well represented in the tropical countries. There are, according to Britton and Brown, about 110 genera and 880 species. A few members of the Rue Family are native to the United States; chief of these are the prickly ash (*Xanthoxylum*), hop-tree (*Ptelea*), and torch-wood (*Amyris*). None of the *Citrus* species are native of America.

KEY TO IMPORTANT GENERA OF RUTACEÆ[1]

Leaves trifoliate, *Poncirus* (trifoliate orange).
Leaves unifoliate.
Ovary three- to seven-celled; ovules two in each cell; stigma cavernous. *Fortunella* (kumquat).
Ovary eight- to fifteen-celled; usually more than two ovules in each cell; stigma solid, *Citrus* (orange, lemon, grapefruit, lime, etc.)

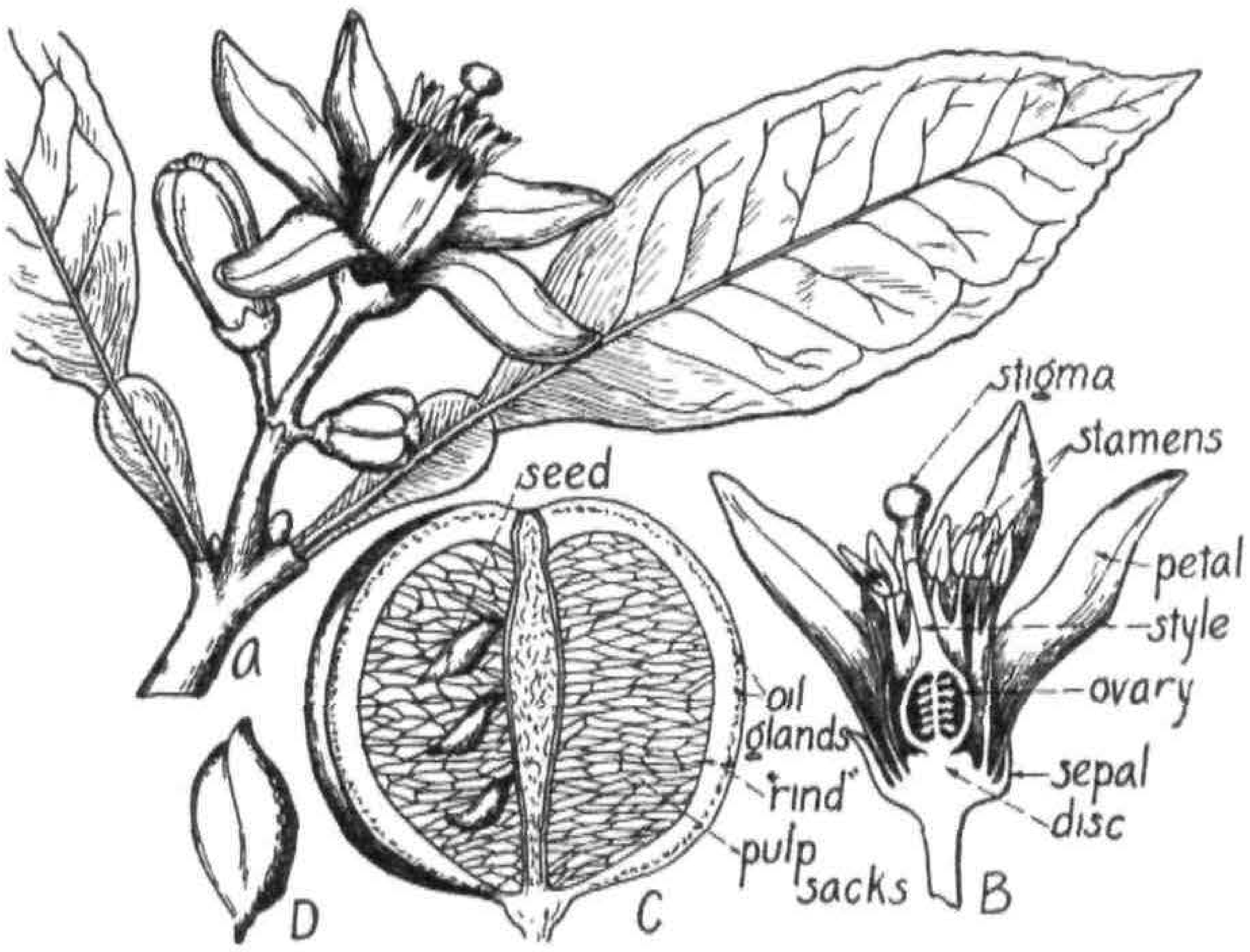


FIG. 201.—Sour orange (Citrus aurantium). *A*, flowering branch; *B*, lengthwise section of flower; *C*, lengthwise section of fruit; *D*, seed. (*After Wossidlo.*)

CITRUS (Citron, Lemon, Orange, etc.)

Citrus species are aromatic, mostly thorny shrubs or small trees with the spines disposed singly in the leaf axils. The sweet orange tree is a surface feeder; almost its entire root system is in the first 18 inches of soil. The sour orange root system penetrates to a much greater depth. The citrus plant is different from most plants in the total absence of root hairs. Absorption is carried on by the fibrous roots which are abundant and capable of rapid growth.

[1] Hume has been followed largely in the discussion of this group.

Leaves —The leaves are glandular-dotted, winged-petiolate, glaucous, leathery, evergreen, and unifoliate (with the exception of *Citrus trifoliate*); the leaf stalk is usually articulated to the blade and also to the twig. The life of the leaf depends upon the kind of wood upon which it is borne. On the fruiting branches, orange leaves, for example, remain on the tree about fifteen months, while on twigs with vigorous vegetative growth they may remain on the tree for three or four years. The leaves of trifoliate oranges fall in the autumn. The aromatic odor of freshly crushed leaves of citrus plants is due to the numerous glands which are scattered over its surface.

Flowers.—The white or purplish-pink flowers are solitary, or in small axillary or terminal cymes or panicles. The flowers are hermaphroditic; the *calyx* is three- to six-toothed; the *corolla* has four to eight separate thick segments (petals); and there are 20 to 60 stamens, united at their bases to form groups; the *ovary* possesses 8 to 75 cells and is subtended by a cushion-shaped disk (receptacle).

Pollination and Fertilization.—Some varieties of citrus plants require fertilization in order to set fruit, while others mature parthenocarpic ("seedless") fruits. Some varieties of oranges require cross-fertilization, and moreover, will not set fruit unless pollen is derived from certain congenial varieties. Pollination may occur without the visitation of insects. The time for complete fertilization after pollination varies from thirty hours in Satsuma oranges to four weeks in trifoliate oranges. Parthenocarpic varieties seldom bear viable pollen. In navel oranges there is no pollen in the anthers at flowering time.

Fruit.—The fruit is a modified berry (hesperidium); it is spherical or spheroidal and is made up of a thick, leathery "rind" with numerous lysigenous oil glands, and a juicy pulp composed of numerous stalked "juice sacks." Bonavia

considers the rind of citrus fruits to consist of a whorl of modified leaves that has grown up about the carpels. The number of carpels ("sections") varies in the same variety.

Seeds.—There are from one to eight light-colored seeds in each cell of the fruit. The seed coat is either leathery or membranous; endosperm is lacking; each seed has two or more embryos with fleshy, hypogean cotyledons. The polyembryonic condition of citrus fruits is characteristic. As many as thirteen seedlings from one seed have been noted. Strasburger has shown that embryos of citrus seeds may be derived from nucellar cells, as well as from fertilized ova. He has designated such embryos as "adventitious." Hence, in the polyembryonic seed, there are two sorts of embryos: (1) those formed by the union of egg nucleus and sperm nucleus, true sexual embryos; and (2) "adventitious" embryos formed by vegetative growth. Obviously, the seedlings from adventitious embryos may be used for propogation with confidence that they will come true to the plant which bore them. Early disintegration of embryo sacs appears to be prevalent in citrus fruit. This may be one cause, along with infertile pollen, of seedless fruits in this group.

Geographical.—Citrus species are mostly natives of the Malay Archipelago, and adjacent Asiatic territory. Citrus fruits are grown only in those parts of the United States where there is an almost continuous growing season, and where freezes seldom occur.

KEY TO PRINCIPAL SPECIES OF CITRUS

Petals white inside, purplish or reddish outside.
  Stamens 30 to 40; fruit 6 to 9 inches long, its skin thick, *C. medica* (citron).
  Stamens 20 to 30; fruit about 3 inches long, its skin medium thick, *C. limonia* (lemon).
Petals white both on the inside and outside.
  Leaves wingless or narrowly winged.
    Fruit small, $1\frac{1}{4}$ to $2\frac{1}{2}$ inches in diameter, its skin thin, *C. aurantifolia* (lime).

Fruit large, its skin thick.
Tree small, 12 to 20 feet tall; skin of fruit easily removed, *C. nobilis* (king orange).
Tree large, 20 to 40 feet high; skin of fruit not easily removed, *C. sinensis* (common sweet orange).
Leaves broadly winged.
Fruit large, pale lemon-yellow when ripe, *C. grandis* (grapefruit, pomelo, shaddock).
Fruit medium-sized, orange-colored or reddish when ripe, *C. aurantium* (sour or Seville orange).

CITRUS MEDICA (Citron)

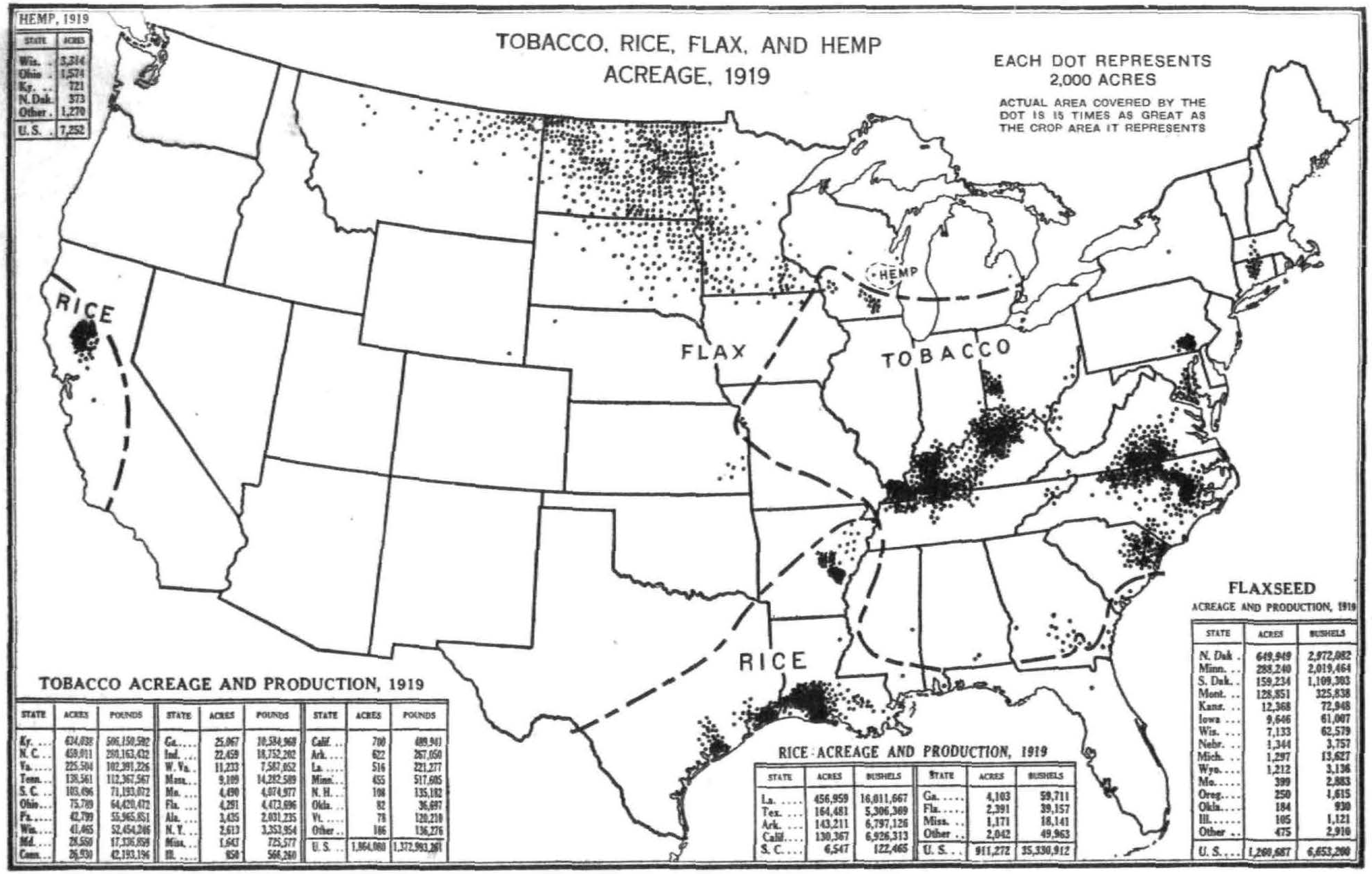
Description.—This is a shrub or small tree with short, stout thorns; the *leaves* are large, crenate or serrate, and its petioles are wingless; the large *flowers* are usually in clusters of 3 to 10; their petals are white above, and reddish purple below; the stamens are as many as 30 or 40; the ovary usually has from 9 to 10 locules; the *fruit* is large, 6 to 9 inches long, rough or warty, lemon-yellow when ripe, its skin thick, the pulp scarce and very acid, and the juice sacks small and slender. In the "fingered citron," the fruit segments are separated into a number of finger-like projections.

Geographical.—This species is probably a native of India. It is cultivated most extensively in the Mediterranean region, and to some extent in this country.

"Citron."—The commercial "citron" is the dried fruit of *Citrus medica*. Before the fruit is candied, it is placed in brine to extract the undesirable oil in the skin. The fruit is then boiled for an hour or so in a sugar solution to which has been added some glucose. The glucose prevents the product from becoming too brittle. It is then allowed to stand in the syrup for about a month, and subsequently boiled in a pure sugar syrup.

CITRUS LIMONIA (Lemon)

Description.—The lemon tree is small, from 10 to 20 feet in height, with short, stout thorns; the *leaves* are 2 to 3 inches



HEMP, 1919

STATE	ACRES
Wis. .	3,314
Ohio .	1,574
Ky. . .	721
N. Dak.	373
Other .	1,270
U. S. .	7,252

TOBACCO ACREAGE AND PRODUCTION, 1919

STATE	ACRES	POUNDS	STATE	ACRES	POUNDS	STATE	ACRES	POUNDS
Ky. . . .	434,038	506,150,582	Ga. . . .	25,067	10,534,968	Calif. . .	700	489,941
N. C. . .	459,011	280,163,432	Ind. . . .	22,459	18,752,282	Ark. . . .	622	267,050
Va. . . .	225,504	102,391,226	W. Va. .	11,233	7,587,052	La. . . .	516	221,277
Tenn. . .	138,561	112,367,567	Mass. . .	9,109	14,282,589	Minn. . .	455	517,605
S. C. . .	103,496	71,193,072	Mo. . . .	4,490	4,074,977	N. H. . .	108	135,182
Ohio. . .	75,789	64,420,472	Fla. . . .	4,291	4,473,696	Okla. . .	92	36,697
Pa. . . .	42,799	55,965,851	Ala. . . .	3,435	2,031,235	Vt. . . .	78	120,210
Wis. . . .	41,465	52,454,246	N. Y. . .	2,613	3,353,954	Other . .	186	136,276
Md. . . .	28,550	17,336,859	Miss. . .	1,643	725,577	U. S. . .	1,864,080	1,372,993,261
Conn. . .	26,930	42,193,196	Ill. . . .	850	566,260			

RICE ACREAGE AND PRODUCTION, 1919

STATE	ACRES	BUSHELS	STATE	ACRES	BUSHELS
La. . . .	456,959	16,011,667	Ga. . . .	4,103	59,711
Tex. . . .	164,481	5,306,369	Fla. . . .	2,391	39,157
Ark. . . .	143,211	6,797,126	Miss. . .	1,171	18,141
Calif. . . .	130,367	6,926,313	Other . .	2,042	49,963
S. C. . . .	6,547	122,465	U. S. . .	911,272	35,330,912

FLAXSEED
ACREAGE AND PRODUCTION, 1919

STATE	ACRES	BUSHELS
N. Dak. .	649,949	2,972,082
Minn. . .	288,240	2,019,464
S. Dak. .	159,234	1,109,303
Mont. . .	128,551	325,838
Kans. . .	12,368	72,948
Iowa . . .	9,646	61,007
Wis. . . .	7,133	62,579
Nebr. . .	1,344	3,757
Mich. . .	1,297	13,627
Wyo. . . .	1,212	3,136
Mo. . . .	399	2,883
Oreg. . . .	250	1,615
Okla. . . .	184	930
Ill.	105	1,121
Other . .	475	2,910
U. S. . . .	1,260,687	6,653,200

FIG. 202.—(*After U. S. Dept. Agri.*)

long, long-ovate, sharp-pointed, serrate, and its petioles wingless; the large *flowers* are axillary, usually solitary, sometimes in small clusters; their petals are white inside, and purplish above; the stamens are usually between 20 and 30 in number; the ovary has 7 to 10 locules. There are three sorts of flowers in the lemon: (1) perfect flowers, (2)

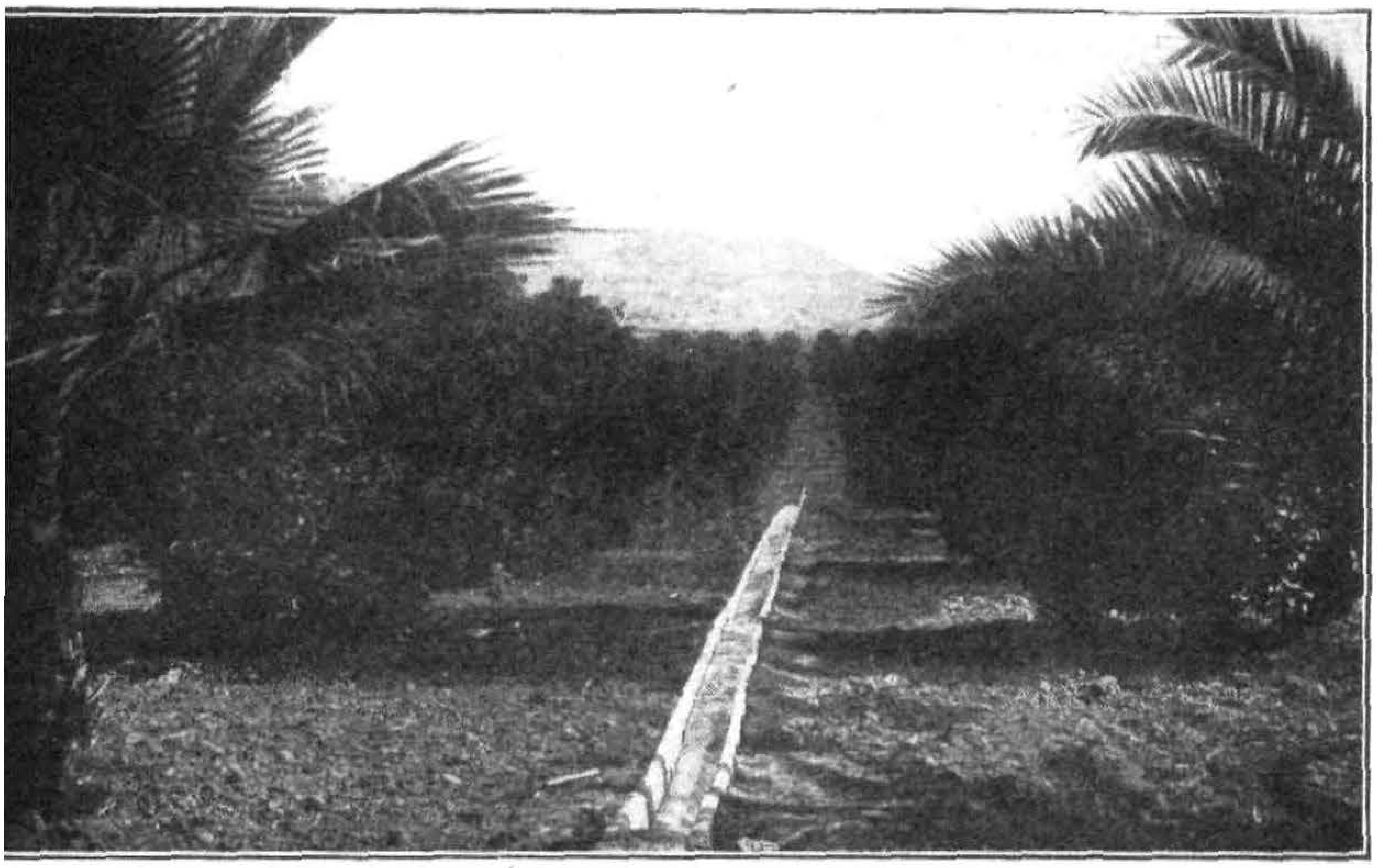


FIG. 203.—A citrus orchard in Southern California. (*From Calif. Agr. Exp. Sta.*)

flowers with rudimentary pistils and normal stamens, and (3) flowers that fail to develop beyond the bud stage. The first class is the only one to set fruit. The *fruit* is about 3 inches long, light yellow when mature, its skin medium thick, the pulp abundant and acid, and the juice sacks long and pointed. The fruit requires about nine months to reach maturity.

Geographical.—The lemon is probably a native of India. It is cultivated extensively in the Mediterranean region, and to a considerable extent in California and Florida.

Color of Lemon Fruit.—Lemons are picked when they reach a size demanded by the market, regardless of the degree of maturity. Hence many of the lemons, when picked, are dark green, and not the lemon-yellow of those we buy in the market. The fruit is colored and ripened before shipment. If they are not to be shipped for several months, they are placed in storage houses where coloring and ripening goes on gradually. However, if they are to be shipped soon after picking, the coloring process is hastened. This is done by putting them in "sweat rooms" that are kept at a temperature between 90° and 95°F. The proper color is obtained by this treatment within four to six days.

Uses.—Lemons are used in the home for lemonade, as an ingredient in a number of prepared foods, as a stain-remover, and as a bleaching agent. One of the chief uses of lemons is in the manufacture of lemon extract.

Lemon Extract.—This ranks second to vanilla extract in the quantity consumed. Sicily now produces the world's supply of lemon oil. Cull lemons are utilized for the production of the oil. Lemon extract is made by dissolving 5 parts of lemon oil in 95 parts of strong alcohol. Lemon oil is secreted by special cells in the outer surface of the rind. About 95 per cent. of the lemon oil produced is obtained from the lemons by the *sponge method*, the remainder by the *machine method*. There are two sponge methods, known as the *two-piece*, and *three-piece* sponge methods. In the former method the lemons are cut by hand into two pieces, and the pulp removed; the rinds are then thoroughly soaked in water, and after standing for several hours, passed on to the spongers. The apparatus of the sponger consists of a round stick about 1 inch in diameter, placed across the top of an earthenware bowl about 8 inches tall and the same in diameter, and three sponges. A flat sponge is hung across the stick, upon this another thicker sponge, and finally a third above this.

CITRUS NOBILIS (King Orange)

Description.—The King orange tree is 12 to 20 feet tall, with slender, drooping branches, and thornless, or with small sharp spines; the *leaves* are small, lanceolate to oval, and the petioles are wingless or very narrowly winged; the *flowers* occur singly or in small clusters; the petals are white above and below, fleshy and recurved; there are from 18 to 24 stamens; the ovary has 9 to 15 locules; the *fruit* is oblate, orange to reddish in color, its peel loose and easily removed, the pulp sweet or sub-acid, and the juice sacks broad and blunt.

Varieties.—*Citrus nobilis* var. *deliciosa* is the *mandarin orange.* In this variety are included the *tangerine* varieties, which have an easily removable skin and segments that come apart readily, also the *tangelo* which is a hybrid between the tangerine and the Bowen grapefruit. *Citrus nobilis* var. *unshiu* is the Satsuma or Unshiu orange. It is a small, spineless, dwarf tree, and very hardy.

CITRUS GRANDIS (Grapefruit, Pomelo, Shaddock)

Description.—This species is a large tree, 20 to 40 feet in height, with slender, flexible spines, if present; the *leaves* are large, ovate, crenate, broadly rounded at the base, and the petioles are broadly winged and articulated; the *flowers* are borne singly or in clusters of 2 to 20; the petals are white both above and below; there are from 20 to 25 stamens, with large linear anthers; the ovary has from 11 to 14 locules; the *fruit* is very large, 4 to 6 inches in diameter, globose, oblate or pear-shaped, pale lemon-yellow when ripe, its skin smooth, the pulp peculiarly acid or sub-acid, and the juice sacks large and spindle-shaped.

Geographical.—The species is a native of Polynesia and the Malay Archipelago. It is now grown in the United States.

Variety and Name.—The name *grapefruit* is the one that this species is known by commercially. *Shaddock* is a horti-

FIG. 204.—Pomelo (Citrus grandis), in the fourth summer. (*From Calif. Agr. Exp. Sta.*)

cultural variety, the fruit of which is much larger than the common grapefruit. It is a coarse, thick-skinned fruit, with

thick, leathery septa between the locules, and is of no commercial importance. The name *pomelo* is now recognized by most horticulturists. Grapefruit as a breakfast fruit is rapidly increasing in popularity.

CITRUS AURANTIUM (Sour or Seville Orange)

Description.—The sour orange tree is 20 to 30 feet high, and bears long, flexible, blunt spines; the *leaves* are 3 to 4 inches long, wedge-shaped at the base, pointed at the tip, and the petioles are broadly winged; the *flowers* are borne singly or in small axillary cymes; the fragrant glandular-dotted petals are white above and below; there are from 20 to 24 stamens; the ovary has 6 to 14 locules; the *fruit* is globose, orange-colored or reddish, rough, the pulp acid, and the juice sacks small and spindle-shaped.

Geographical.—The sour orange is probably a native of southeastern Asia. It is cultivated in the United States, being used as a stock on which to bud other citrus fruits.

Other Species of Citrus.—Other *Citrus* species of less commercial importance in the United States are *C. mitis*, the Calamondin orange, *V. ichangensis*, Ichang lemon, and *C. bergamia*, bergamot.

FORTUNELLA (Citrus) (Kumquat or Kinkan)

Description.—The kumquats are evergreen shrubs with simple, glandular *leaves;* the scented white *flowers* are single or in clusters of three or four, and axillary; the early flowers in the spring are usually without pistils; there are four times as many stamens as petals; the ovary has three to seven cells, and each cell contains two ovules; a characteristic feature of the flower is the cavernous stigma; the *fruit* is small, 1 to 1¼ inches in diameter, its rind usually thick fleshy, spicy, and aromatic, its juice acid, and its seeds small and pointed;

there may be one or two crops of bloom and fruit in a growing season.

Species.—The two most common species of *Fortunella* are *F. margarita*, the Oval or Nagami kumquat, and *F.*

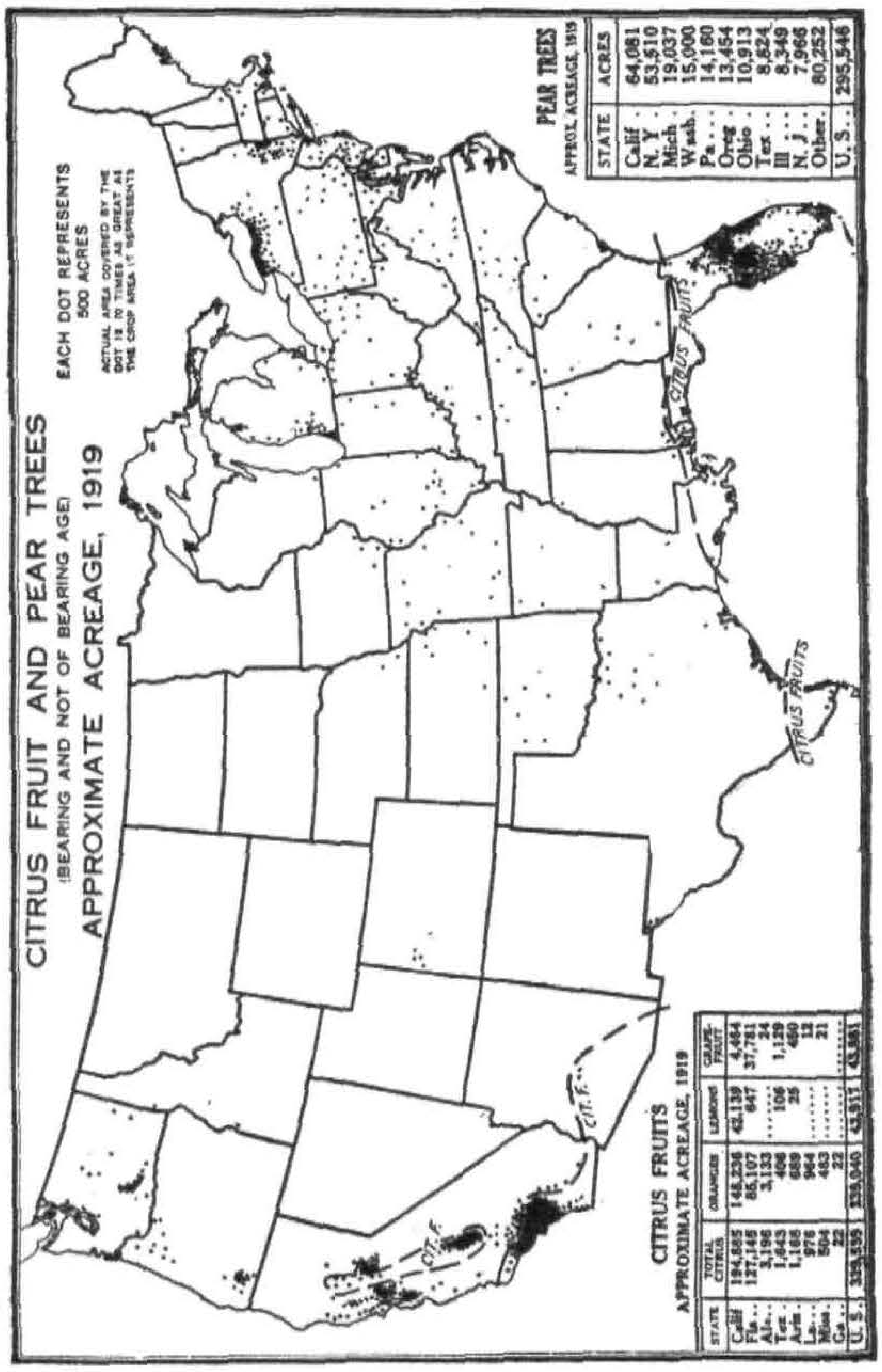


FIG. 205.—(*After U. S. Dept. Agri.*)

japonica, the Round of Marumi kumquat. The former is a thornless shrub or small tree with oval fruit, the latter a thorny shrub with globose fruit. *F. crassifolia* is the Meiwa kumquat, and *F. hindsii*, the Hongkong wild kumquat.

The latter is considered by Swingle to be the wild stem form of our *Citrus* species.

Uses.—The kumquats are shrubs grown as ornamentals, and also for their fruit, which is eaten raw and entire.

PONCIRUS (Trifoliate Orange)

Description.—The trifoliate orange is a low tree, seldom over 15 feet high; the older branches are thorny, the thorns being 1 to 1½ inches long, and flattened at the base; the characteristic deciduous trifoliate *leaves* are composed of thin, elliptical, crenate of dentate leaflets; the *flowers* usually appear before the leaves, singly or in pairs in the leaf axils; the five sepals are greenish yellow in color, and pointed at the tip; the corolla is white; the *fruit* has a light orange color, is rough, and covered with short hairs; it is of no commercial value; the numerous *seeds* differ from those of other allies in being oval, rounded at one end and blunt-pointed at the other. The pulp is acid, bitter, and gummy.

A Hardy Orange.—The trifoliate orange is a native of China and Japan. It is the hardiest of our citrus species, and for that reason has been used in crosses with less hardy, but more desirable species, in the hope that hybrid forms would be secured which would combine hardiness and desirable fruit characters. Hybrids of trifoliate and sweet oranges are known as *citranges*. Varieties of citranges are Colman, Morton, Rusk, Rustic, and Savage.

References

Biermann, M.: On the Structure and Development of the Fruit of Citrus Vulgaris. Arch. Pharm., 235: 19–28, 1897.

Bonavia, E.: Oranges and Lemons of India, vol. i.

Coit, J. E.: A Study of the Factors Influencing Seed Formation in Citrus Fruits. Calif. Agr. Exp. Sta. Rpt., 105–106, 1914.

Citrus Fruits. The MacMillan Co., 1915.

HOOD, S. C., and RUSSELL, G. A.: The Production of Sweet-orange Oil and a New Machine for Peeling Citrus Fruits. U. S. Dept. Agr. Bull. 399: 1–19, 1916.

HUME, H. HAROLD: Pomelos. Fla. Agr. Exp. Sta. Bull. 58: 385–421, 1901.

The Kumquats. Fla. Agr. Exp. Sta. Bull. 65: 555–566, 1902.

The Mandarin Orange Group. Fla. Agr .Exp. Sta. Bull. 66:571–594, 1903

Citrus Fruits and Their Culture. Orange Judd Co., 1913.

IKEDA, TOMOCHIKA: On the Parthenocarpy of Citrus Fruits. Jour. Sci. Agr. Soc. Tokyo, 63, 1904.

OSAWA, I.: Cytological and Experimental Studies in Citrus. Jour. Col. Agr. Imp. Univ. Tokyo, 4: 83–116, 1912.

STRASBURGER, E.: Über Polyembryonie. Jenaisch. Zeitsch. Naturwiss., 12: 647–670, 1878.

WEBBER, H. J.: Complications in Citrus Hybridization Caused by Polyembryony. Science, n. s., 11: 308, 1900.

CHAPTER XXXII

VITACEÆ (Grape Family)

Family Description.—Members of the grape family are either climbers or erect shrubs with nodose joints. There is an abundance of watery sap. The *leaves* are alternate and petioled, either simple (*Vitis*) or compound (*Parthenocissus*) (Fig. 206). The inflorescence is commonly a panicle (*Vitis*) or a cyme (*Parthenocissus*). The *flowers* (Fig. 210) are small, greenish, perfect or polygamo-diœcious (perfect flowers on one individual and imperfect on another). The *calyx* is entire or four- to five-toothed. The four to five *petals* are either separate or united and fall away very soon after development. *Stamens* are four to five in number and opposite the petals. The single *ovary* has two to six cells with one to two ovules in each locule. The *fruit* is commonly a two-celled berry.

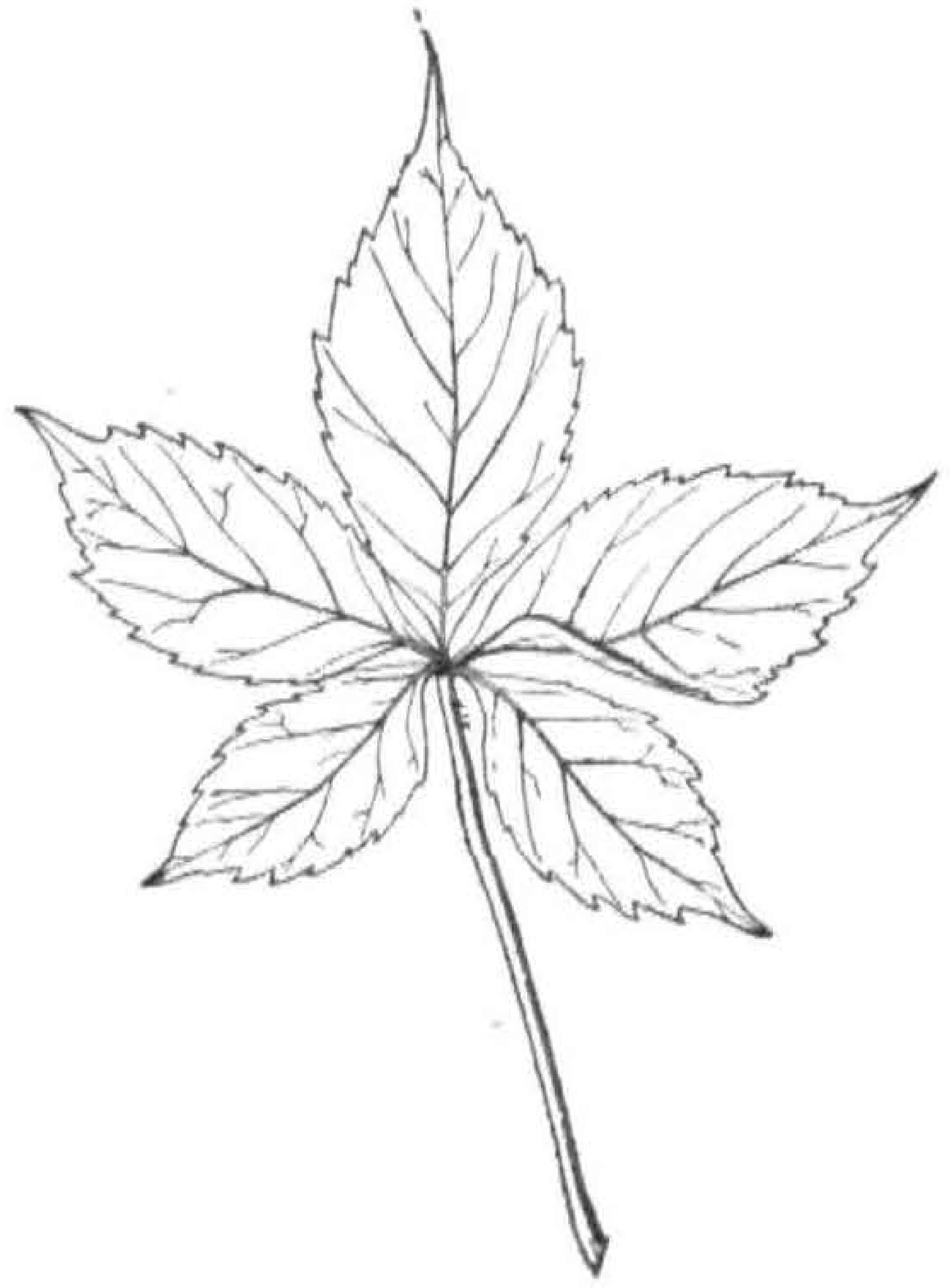


FIG. 206.—Compound digitate leaf of Virginia creeper (Parthenocissus quinquefolia).

Geographical.—There are about 10 genera and 450 species in this family, many of which are natives to tropical countries.

KEY TO IMPORTANT GENERA

The three most important genera are *Vitis* (grape), *Cissus* (pepper vine) and *Parthenocissus* (Virginia Creeper and American Ivy). These may be distinguished as follows (as far as our species are concerned):

Leaves simple or pinnately compound.
  Petals united into a cap, falling away without separating (Fig. 210), *Vitis* (grape).
  Petals separate, spreading, *Cissus* (pepper vine).
Leaves digitately compound, *Parthenocissus* (Virginia creeper, American ivy).

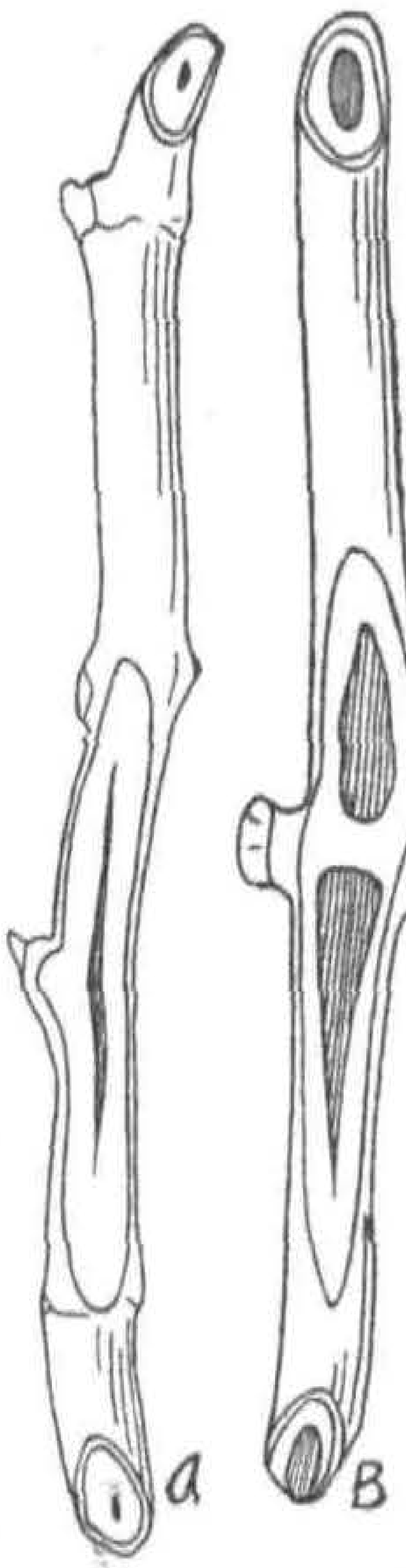


FIG. 207.—Two types of grape stems cut in median lengthwise section *A*, southern fox grape (Vitis rotundifolia) with pith continuous at the nodes; *B*, old world grape (V. vinifera) with pith interrupted at the nodes. (*After Hedrick.*)

VITIS (Grape)

Stems.—Grapes are climbing or woody vines with tendrils. The stem is jointed. The internodes have a large pith. In many species there is a woody tissue (diaphragm) at the nodes separating the pith; in others this woody tissue is absent (Fig. 207). In pruning the vines, the practice is to make the cut through the nodes rather than through the internodes; by cutting through an internode, the pith shrinks, leaving a hollow in which water may collect and rotting set in. Grapes have a tendency to produce suckers and water sprouts. The former arise from below or near the surface of the ground and should be removed. Water sprouts arise from dormant buds above ground. They do not produce fruit. If dormant buds develop, producing these sterile shoots, it indicates that there is not a sufficient number of fruit buds to take care of all the sap coming to aerial parts. Water sprouts should be removed during winter pruning.

Tendrils of grapes, morphologically, are modified stems. This is shown by the fact that they sometimes bear small

leaves or flowers. In the Fox grape (Fig. 208), there is either a tendril or an inflorescence opposite each leaf. This continuity is somewhat variable, however. In all other species, there

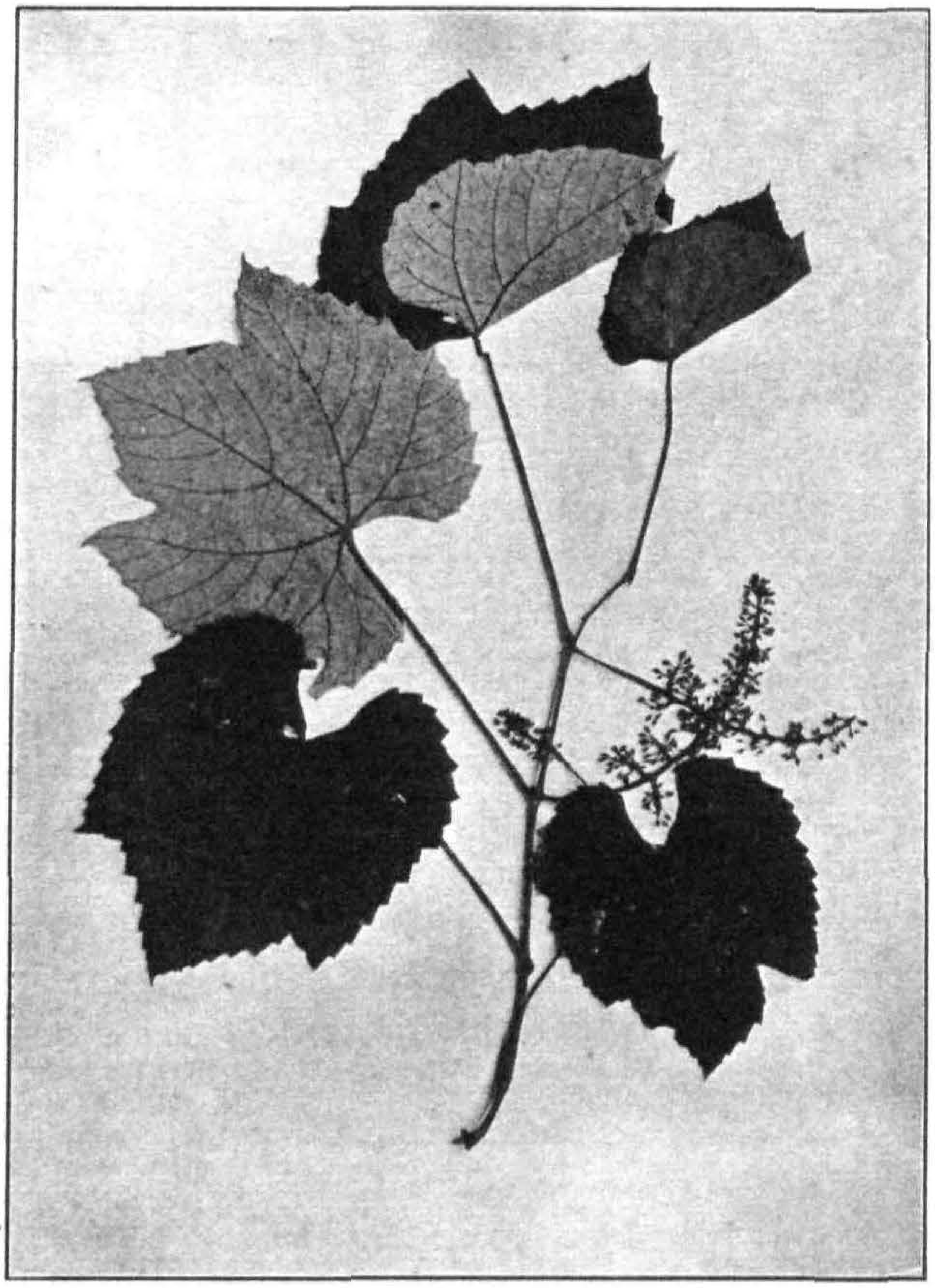


FIG. 208.—Northern fox grape (Vitis labrusca).

are two successive leaves with a tendril or inflorescence opposite each, while the third leaf is without a tendril, and so on, there being no tendril or cluster for each third leaf (Fig. 209). A tendril or inflorescence terminates the stem growth.

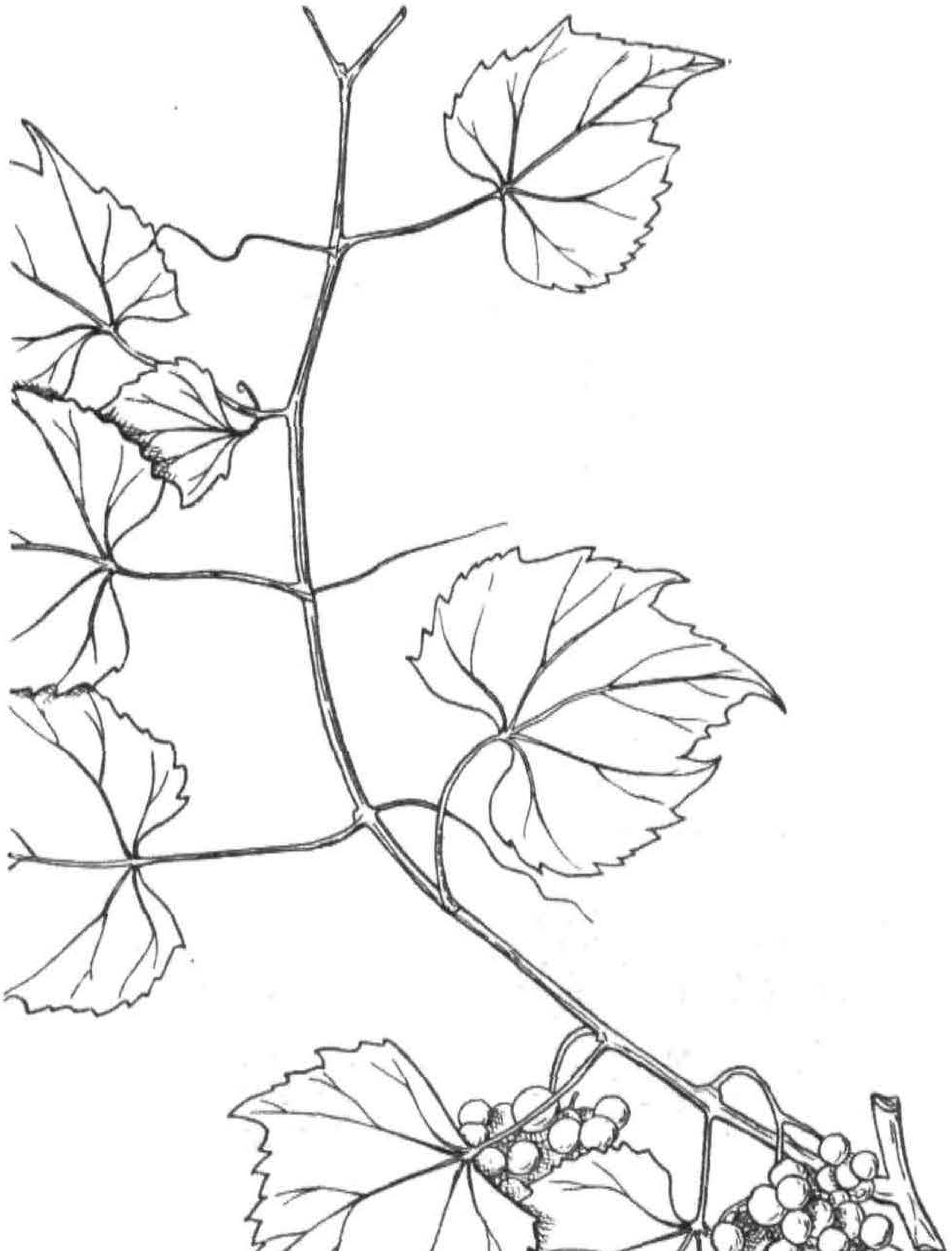


FIG. 209.—Fruit-bearing shoot of river-bank grape (Vitis riparia). (*After Hedrick.*)

As in the blackberry and raspberry, the flower buds of grape are mixed and the inflorescences are terminal. When a flower bud opens, a leafy shoot, terminated by a flower cluster, developes; but very soon, a bud in the axil of the topmost leaf of this shoot is formed, which continues the growth of the shoot. It thus pushes the flower cluster to one side, so that it seems to be lateral, rather than terminal, in origin. A number of flower clusters may be formed in succession on the same shoot in the manner described. *Vitis labrusca* averages three to six clusters to a cane; all other species average two to a cane. This shoot bears a number of buds, each of which may, the following season, produce another shoot, in turn bearing fruit clusters. If all these buds are allowed to develop, the fruit developed on the shoots will be very small. Hence in practice it is found necessary, each year, to prune back the current season's growth, leaving only a few buds to develop the succeeding year.

Grapes are commonly propagated from stem cuttings. The European grape has been grown vegetatively for over 5,000 years.

Leaves.—The grape leaf is simple, palmately lobed or dentate, alternate, with grooved petiole and small stipules. The leaves of the different species vary as to size, shape, number of lobes, nature of petiolar groove, and surface.

Inflorescence and Flowers.—The grape inflorescence is a compact panicle. As has been stated, the clusters are borne at the basal nodes of the current season's growth, opposite a leaf or a tendril. In *Vitis labrusca,* there are from three to six inflorescences to a cane, while in all other species the average is two inflorescences per cane.

In the wild state, grape vines are of two types: some vines bear self-sterile perfect flowers and other vines bear only staminate flowers. In cultivated forms, there are two types

of perfect flowers; those in which the stamens are upright and those in which the stamens are reflexed. In the first case, the pistil is fully developed and the pollen potent, while in those flowers with reflexed stamens, the pollen is more or less impotent. Flowers without stamens do not occur.

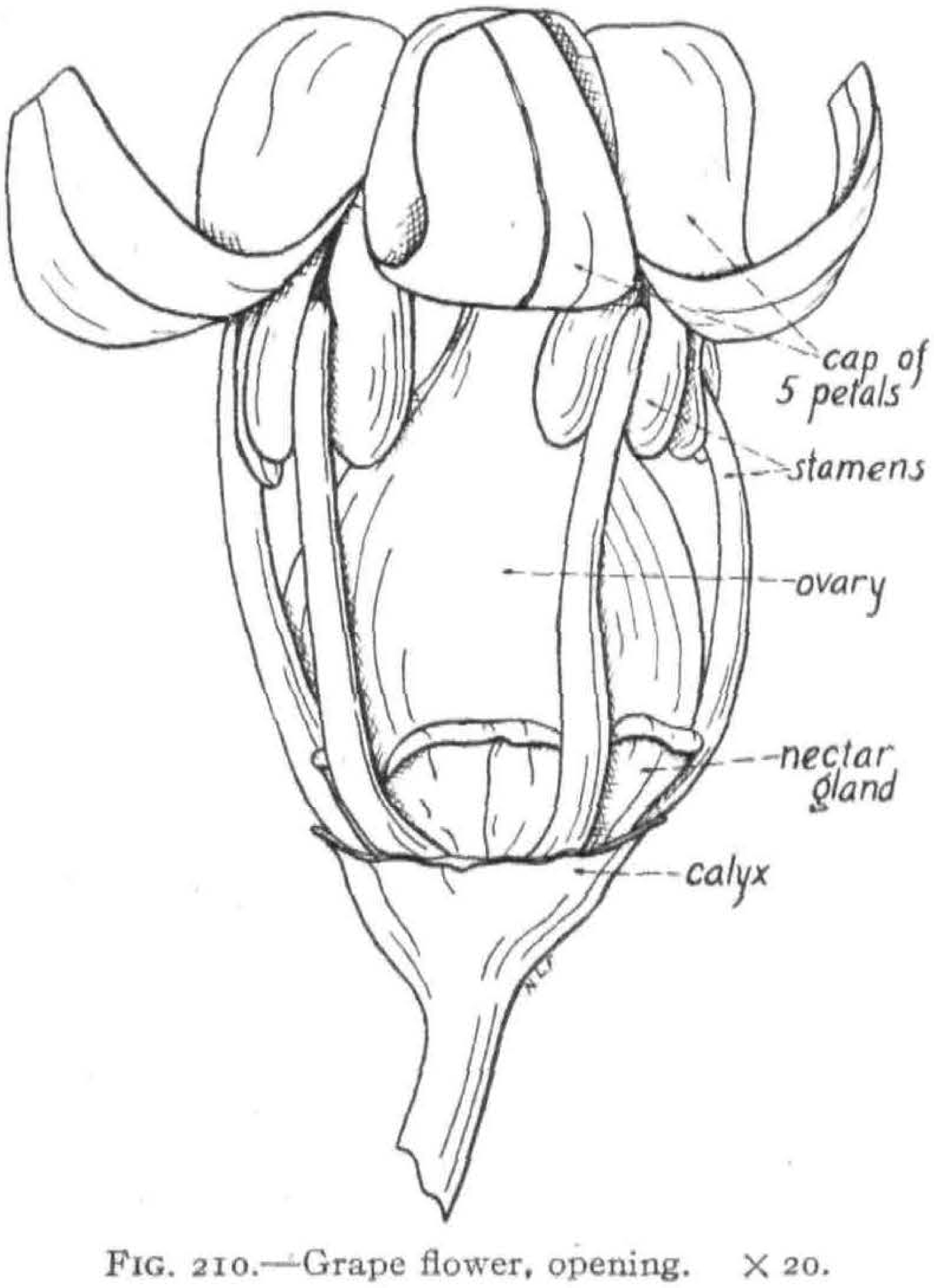


FIG. 210.—Grape flower, opening. × 20.

Among cultivated European varieties, only perfect flowers are common. This has resulted from selection.

The *flowers* (Fig. 210) are hypogynous and regular. The *calyx* consists of a narrow rim at the base of the flower. The *corolla* has five united, greenish petals; in the bud, they form a cap (Fig. 210) over the stamens and pistils. When the flower opens, the petals become loosened at the base but

remain united by the tips. *Stamens* are five in number and there is an equal number of nectar glands between. The one *pistil* is two-celled and two-ovuled. The *fruit* is a berry.

Marked variations occur in the flowers of the genus *Vitis:* stamens may vary from three to nine; petals, nectariferous glands, and carpels have a corresponding numerical variation.

Opening of Flower and Pollination.—*Flower Opening.*—The opening of the grape flower is indicated by the breaking away of the petals at the base (Fig. 210). In some instances, all the petals break away at about the same time; at other times, one petal may initiate the process, and be followed by the others. The cap of five petals, adhering at their apices, finally falls off. The rate of flower opening varies from a few minutes to several hours. The anthers seldom open until the cap falls off. Most grapes are insect pollinated.

Self-sterility.—Many cultivated varieties of grapes are self-sterile; this is due, for the most part, to impotent pollen. Some cultivated varieties are perfectly self-fertile, others partially self-fertile, and still others entirely self-sterile. As has been stated, perfect flowers bearing reflexed stamens usually have impotent pollen. However, in some cases, perfect flowers with erect stamens also bear impotent pollen. As a rule, the self-fertile varieties, those that can develop marketable clusters when self-fertilized, have long stamens. Self-sterile varieties, those that cannot produce marketable clusters of fruit when self-fertilized, usually possess short stamens. However, long stamens and short stamens are not absolute criteria of self-fertility and self-sterility respectively. With but few exceptions, the strongly self-sterile varieties are hybrids. Booth suggests that the grape is "now in a state of evolution from an assumed older hermaphrodite form to forms which are essentially staminate

and pistillate." He finds all gradations between "pseudo-staminate" and "pseudo-pistillate" forms among wild species.

Grape Pollen.—In a study of grape pollen, Booth found that self-sterile pollen differs from self-fertile pollen. In the self-fertile form, the grain is surrounded by a mucilaginous substance which causes them to stick together; the grain is oblong in shape, symmetrical, and blunt at the ends. Self-sterile pollen has no mucilaginous substance about it; it is irregular in shape and more pointed at the ends. Self-fertile and self-fertile pollen may be mixed in the same variety. The degree of self-sterility or self-fertility seems to vary with environmental conditions.

"Couloure" of Muscat Grape.—This valuable raisin grape has a tendency to drop its blossoms without setting fruit. This trouble is known as "couloure." It results from a lack of fertilization. This is due to the fact that in this variety stamens are shorter than the pistil, that the pollen has a tendency to stick together in masses which makes its distribution less certain, and to the rather frequent development of imperfect pollen grains. The difficulty is largely overcome by planting, in the Muscat vineyard, varieties that produce an abundance of viable pollen, and that blossom at the same time as the Muscat. These varieties will furnish pollen for fertilization of Muscat flowers.

Flowers in Wild Grapes.—Grapes in the native condition differ from those in cultivation. The wild forms seldom bear self-fertile perfect flowers. In these, there are just two sorts of vines: (1) staminate, and (2) self-sterile hermaphrodite. There are no self-fertile hermaphrodites. The staminate flowers have abortive pistils, and the so-called pistillate forms retain their stamens, but they are abortive.

KEY TO MOST IMPORTANT SPECIES OF VITIS[1]

Skin of mature berry not separating freely from the pulp, *Vitis vinifera* (Old World grape).

Skin of mature berry separating readily from the pulp.

- Nodes without diaphragms (Fig. 207, A); tendrils forked, *Vitis rotundifolia* (Southern fox grape).
- Nodes with diaphragms (Fig. 207, B); tendrils forked,
  - Leaves and shoots glabrous at maturity and without bloom.
    - Leaves broader than long; petiolar sinus usually wide and shallow, *V. rupestris* (sand grape).
    - Leaves ovate in outline; petiolar sinus usually medium to narrow, *V. riparia* (river bark grape).
  - Leaves rusty or white tomentose or glaucous blue below.
    - Leaves not covered with a thick, dense felt-like tomentum when fully grown, *V. æstivalis* (summer grape).
    - Leaves covered with a dense, thick, felt-like tomentum when fully grown, *V. labrusca* (Northern fox grape).

Vitis vinifera (Old-World Grape, Wine Grape, Raisin Grape).—The Old-World grape is not as large a plant as most American species. The *leaves* are thin, smooth, and three- to seven-lobed; they may be smooth or woolly-hairy when young; the lobes are rounded or pointed, and their margins coarsely toothed. The oval, oblong, or globular berries are in long and broad clusters.

The varieties of this species have a high sugar content. On this account, they make better wine and raisins than American varieties. American varieties are table grapes; European varieties are wine and raisin grapes. The latter are now grown in California, where the wine and raisin industries have developed to considerable importance. *V. vinifera* is not resistant to the attacks of *Phylloxera*, a scale attacking the leaves and roots. American varieties are comparatively more resistant to these insects and on this account are used as stocks upon which European varieties are grafted.

[1] The key is adapted from "The Grapes of New York," by Hedrick.

Vitis vinifera is probably a native of western and southern Asia.

Vitis rotundifolia (**Southern Fox Grape**).—This is usually a very vigorous, high-climbing grape, with hard wood and smooth bark. The leaves are broadly heart-shaped, with coarse, blunt teeth, light green in color, smooth above and below or sometimes slightly hairy on the veins below. The large, spherical, black or greenish-yellow berries are in small loose clusters. It grows wild from southern Delaware to Missouri, Texas, and the Gulf States.

The varieties of this species are known as Muscadine grapes. One of the chief varieties is the Scuppernong.

Vitis rupestris (**Sand Grape**).—This is a low shrub with small, broadly heart-shaped, slightly lobed leaves with coarsely toothed margins. The small, black or purple-black berries are in small clusters.

This species is southern in its distribution, reaching southern Pennsylvania as its northernmost limit. It is very resistant to rot and mildew of the foliage.

Vitis riparia (**River-bank Grape**).—The river-bank grape is a rather vigorous climbing plant with smooth and slender twigs. The leaves have large stipules; the margin has sharp teeth that vary in size. The berries are small, black, coated with a bloom, and occur in rather compact, but small clusters.

This is the most widely distributed and the hardiest of American grapes. It is common on stream banks in the United States east of the Rocky Mountains.

Vitis aestivalis (**Summer Grape**).—This is a strong-growing species with leaves that are short-stipulate, thick, three- to five-lobed, shallowly dentate, dark green above and rusty pubescent beneath. The berries are astringent, of average size, and usually in long clusters.

This species is native to southeastern United States. Its varieties are wine grapes.

Vitis labrusca (**Northern Fox Grape**).—This is a stocky plant with large, heart-shaped leaves which are either entire or three-lobed, dark green above, and densely pubescent below. The clusters of thick-skinned berries are medium to large.

By far the greatest number of cultivated grapes are varieties of this species, or hybrids from it and other species, chiefly *Vitis vinifera*, the Old-World grape.

Varieties of Table Grapes.—There are four very common varieties of table grapes:

1. *Catawba*, hybrid of *V. labrusca* and *V. vinifera*.
2. *Delaware*, hybrid of *V. labrusca* and *V. bourquiniana*.
3. *Niagara*, hybrid of *V. labrusca* and *V. vinifera*.
4. *Concord*, variety of *V. labrusca*.

Color of Grapes.—Varieties of grapes may be grouped as to color as follows:

1. *Berries Purplish-black to Black.*—America, August Giant, Bacchus, Black Hamburg, Canada, Champion, Concord, Ives, Mills, Muscat, Hamburg, Norton.

2. *Berries Purplish-red.*—Agawam, Brighton, Catawba, Delaware, Diana, Iona, Jefferson, Lutie, Massasoit, Red Eagle, Rochester, Vergennes.

3. *Berries Light Green.*—Colerain, Croton, Diamond, Duchess, Elvira, Grein Golden, Lady, Niagara, Triumph.

Wine and Raisin Grapes.—As has been pointed out, the European grape is a wine and raisin grape. Some varieties such as Petite Sirah, Beclan, Mondeuse, Verdot, Lagrain, Refosco, etc., are adapted to the manufacture of dry, white wines; Grenache, Mission, Palomino, and Boal, are a few varieties from which sweet wine is made; while some common raisin grapes are White Muscat of Alexandria, Malaga, and Sultanina.

Uses.—*Dried Grapes.*—These are known under the names "raisins," "Sultanas," and "English," "Corinth" or "Zanta currants." Thin-skinned varieties, such as Vinifera grapes, whose seeds do not adhere to the pulp, are preferable for raisins. "Sultanas" are small light-colored raisins made from a small, seedless grape. "English, "Corinth" or

"Zanta currants" are small dried grapes, grown chiefly in the south of Greece. Table raisins are made from the most select grapes, and usually dried in the sun, without preliminary dipping. The lower grades of grapes that are made into raisins for cooking purposes are nearly always dipped in weak lye before they are dried. California produces almost all the raisins of the United States. According to the census of 1910 the production of raisins and dried grapes in the United States amounted to 169,245,100 pounds, of which California furnished 169,210,675 pounds.

Wines.—There are two well-known sorts of wines: (1) *dry wines*, and (2) *sweet wines*. Dry wines are those in which the grape sugar has been converted into alcohol through fermentation. Sweet wines are those in which the grape sugar has not been converted into alcohol, but the process of fermentation has been prevented by adding alcohol. There are two groups of dry wines: (1) *red wines* (clarets, Burgundies, etc.); and (2) *white wines* (Hocks, Rieslings, etc.). Red wines are made from colored grapes, the skins usually furnishing the coloring matter for the fermenting juice. In the making of red wines, the skins and pulp are crushed and placed in fermenting vats. The unfermented grape juice is termed "must." Fermentation is brought about by the activity of yeast plants, and in this process, the conversion of sugar to alcohol takes place. After the completion of fermentation, the wine is drained from the pomace (skins and other solid material of the grape) and stored in various sorts of receptacles. A slow fermentation goes on in storage, and during this period, settlings accumulate, which are finally removed, leaving the clear wine product.

White wines are made from white grapes, or from those colored grapes with a colorless juice. The coloring matter in the skin is not permitted to get into the juice, as the

skins are removed by pressing, and the juice allowed to ferment alone.

The two chief sweet wines in this country are the ports and angelicas. Port wines are made from colored grapes. The fruit is crushed and allowed to ferment; however, the process of fermentation is not allowed to proceed far, but is stopped by the addition of alcohol. This adding of alcohol to stop the fermentation process is called "fortifying." In the making of angelica wines, the grapes are crushed, pressed immediately to remove the pomace, and the juice permitted to ferment until the desired degree of sweetness is attained, and then the process of fermentation stopped by "fortifying."

Brandy.—Brandies are made both from white wines and red wines. Pure "cognac" is obtained from the distillation of French white wine. The inferior grades of brandy come from the distillation of inferior sorts of wine.

Vinegar.—Grape vinegar is made from white and red wines giving white and red vinegars respectively. Many grapes unsuited for drying, shipping, or wine-making can be turned into excellent vinegars.

Other Uses.—Grapes are a common fresh dessert. The unfermented juice is sold in large quantities in bottles. A good table syrup can be made from some varieties. The wood is sometimes used in the manufacture of baskets, furniture, and rustic work. The plants are ornamental and are frequently turned into arbors. There are a number of by-products from the grape plant. Brandy, feed, fertilizers, and acetic acid are made from the pomace. Tartaric acid is manufactured from the stems, shells and the "lees" of wine. The seeds are used as a food for stock and as a source of tannin and grape oil. A brandy has been made by fermenting the sugary substance that sticks to the seeds, and this material may also be made into a syrup.

References

BEACH, S. A.: Notes on Self-pollination of the Grape. N. Y. State Agr. Exp. Sta. Ann. Rept. 11: 597–606, 1892.

Self-fertility of the Grape. N. Y. State Agr. Exp. Sta. Bull. 157: 397–441, 1898.

Fertilizing Self-sterile Grapes. N. Y. State Agr. Exp. Sta. Bull. 169: 331–371, 1899.

BOOTH, N. O.: A Study of Grape Pollen. N. Y. Agr. Exp. Sta. Bull. 224: 291–302, 1902.

DORSEY, M. J.: Variation Studies of the Venation Angles and Leaf Dimensions in Vitis. Am. Breeders' Assn., 7: 227–250, 1911.

Variation in the Floral Structure of Vitis. Bul. Torrey Bot. Club, 39: 37–52, 1912.

Pollen Development in Vitis with Special Reference to Sterility. Minn. Agr. Exp. Sta. Bull. 144: 1–60, 1914.

Pollen Sterility in Grapes. Jour. Hered., 6: 243–249, 1915.

HEDRICK, V. P.: The Grapes of New York. 15th Ann. Rept. N. Y. Agr. Exp. Sta., vol. 3, part 2: 1–564, 1908.

HUSMANN, GEORGE C., and DEARING, CHARLES: The Muscadine Grapes. U. S. Dept. Agr. Bur. Plant Ind. Bull. 273: 1–64, 1913.

MUNSON, T. V.: Investigation and Improvement of American Grapes. Texas Agr. Exp. Sta. Bull. 56: 217–285, 1899.

RABAK, FRANK: The Utilization of Waste Raisin Seeds. U. S. Dept. Agr., Bur. Plant Indus. Bull. 276: 1–36, 1913.

REIMER, F. C., and DETJEN, L. R.: Self-sterility of the Scuppernong and Other Muscadine Grapes. N. C. Agr. Exp. Sta. Bull. 209: 1–23, 1910.

Fruit and Seeds.—The *fruit* is a several-celled capsule (rarely a berry). The *seeds* are kidney-shaped, globose or obovoid, and have large cotyledons and either little or abundant endosperm.

Geographical.—Members of the family are widely distributed in tropical and temperate regions. There are about 40 genera and 800 species.

Economic Importance.—The mallow family possesses one of our most valuable economic plants—cotton (Gossypium). Cotton is the chief fiber plant of the world. It is grown throughout tropical and subtropical regions. Another crop plant is okra or gumbo (*Hibiscus esculentus*). *Althaea officinalis* is the marsh mallow, the roots of which are used principally for mucilage and for medicinal purposes. Ornamental representatives are hollyhock (*Althæa rosea*), mallow (*Malva* spp.), poppy mallow (*Callirhoë* spp.), *Abutilon* and *Hibiscus*. The Rose of Sharon is *Hibiscus syriacus*.

KEY TO IMPORTANT GENERA OF MALVACEÆ

Stamen column anther-bearing at the summit.
- Carpels one-seeded.
  - Involucre of six to nine bractlets, *Althæa* (marsh mallow and hollyhock).
  - Involucre of one to three bractlets, or none.
    - Petals notched at the apex, *Malva* (mallow).
    - Petals erose at the apex, *Callirhoë* (poppy mallow).
- Carpels two- to several-seeded, *Abutilon*.

Stamen column anther-bearing below the summit (Fig. 212).
- Bractlets of involucre, numerous, *Hibiscus*.
- Bractlets of involucre, three *Gossypium* (cotton).

GOSSYPIUM (Cotton)

Habit of Plants, and Roots.—There are more than 40 species of *Gossypium*, all of which are perennial in their native home. There are herbaceous, shrubby, and tree-like species. In cultivation, the plants are annual or biennial, and herbaceous.

There is a long, branching, and deeply penetrating tap root. This extends to a depth of 2 feet or more in sandy soil. There are four rows of lateral roots from four shallow grooves that run lengthwise on the main root. The lateral roots are only a few inches below the soil surface.

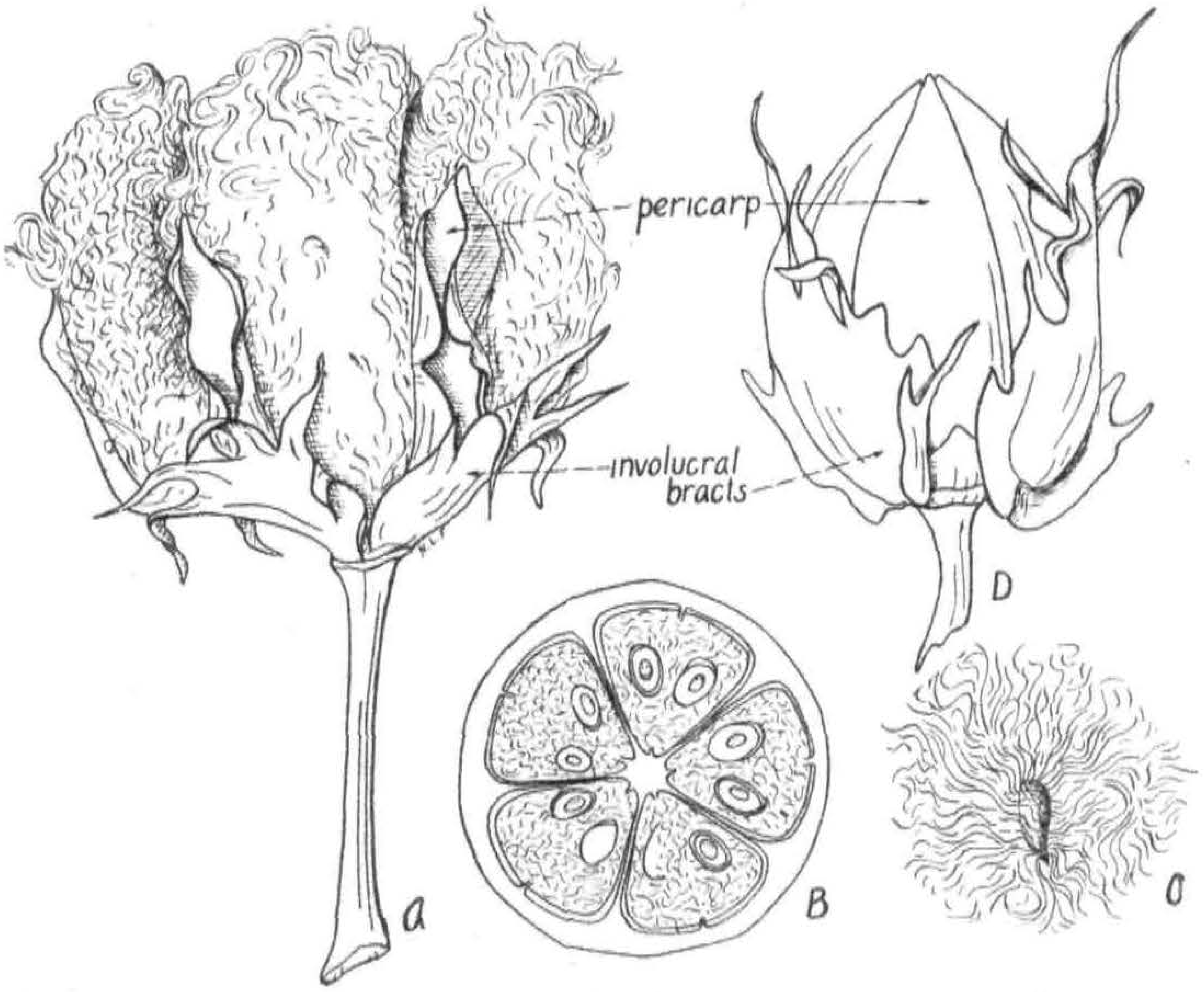


FIG. 213.—Upland cotton (Gossypium hirsutum). *A*, mature boll opened out; *B*, cross-section of young boll; *C*, single seed with fibers; *D*, young boll.

Stems.—The main stems are erect and branching. The usual height of Upland cotton plants is 2½ to 4 feet. The branches may be slender or stocky and are usually spreading.

Kinds of Branches.—There are two sorts of branches in the cotton plant: (1) *Vegetative branches* or "limbs," and (2) *fruiting branches*. There are two buds at the base of each leaf. One of these is a *true axillary* bud, the other one, *extra-axillary*. Vegetative branches or limbs may arise from either axillary or extra-axillary buds. Normal fruit-

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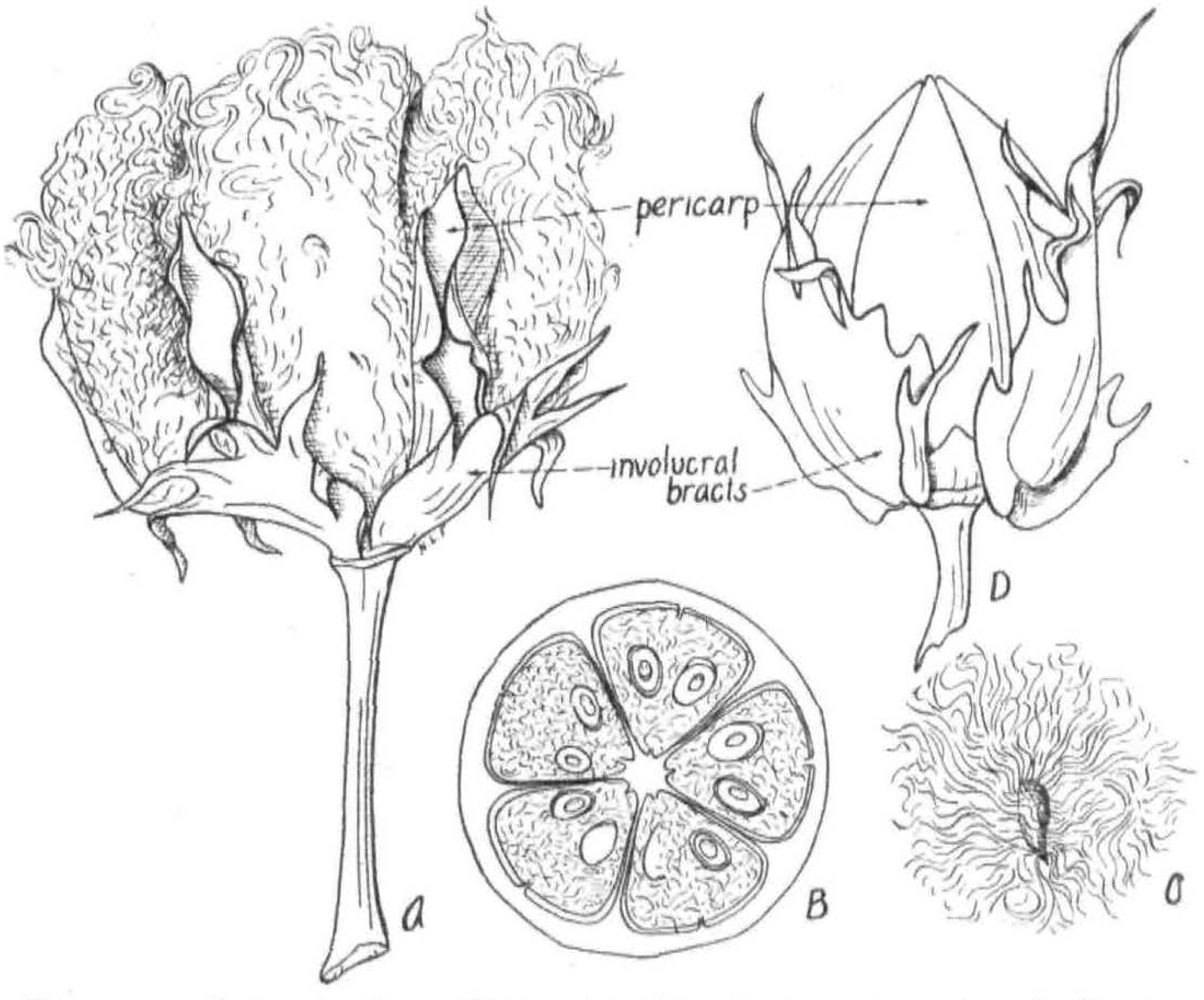

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ing branches arise only from extra-axillary buds. It frequently happens that both a fruiting and a vegetative branch arise at one node, that is, both the extra-axillary and true axillary buds develop. Ordinarily, however, only one bud at a node develops. The axillary buds usually develop into branches at only a few nodes on the lower part of the main stem. The accompanying extra-laterals remain dormant. On the other hand, the upper true axillary buds normally fail to develop, while each of their accompanying extra-laterals forms a fruiting branch. Hence, in most cultivated cotton varieties, no fruiting branches occur on the lower part of the main stem.

In Upland varieties the fourth or fifth node is the first at which fruiting branches are produced; in Egyptian cotton, the first fruiting branches are produced from the eighth to the fourteenth nodes.

Vegetative and fruiting branches differ from each other in other ways than origin. The former makes a small angle with the stem from which they arise, while fruiting branches are more horizontal. Vegetative branches produce no flower buds, while fruiting branches bear a flower bud opposite each leaf. Vegetative branches are frequently as long as the main axis, while fruiting branches are much shorter. The basal internode of fruiting branches is usually longer than the others. The difference in length is much more pronounced in Egyptian cotton than in Upland cotton. The internodes of vegetative branches are about equal in length. Vegetative branches may form both fruiting and secondary vegetative branches, but fruiting branches seldom bear secondary fruiting branches or vegetative branches. Cottons with short-jointed fruiting branches are more productive and usually earlier than those with fewer and longer internodes.

Form of Plant.—The general form of the cotton plant is determined to a large extent by the length and number of

vegetative branches, as well as by the angle they make with the main axis. The plant may consist of a single stalk with a number of fruiting branches but no vegetative branches. An excessive development of lower vegetative branches makes a bushy plant.

Branch Zones.—The cotton plant frequently has three branch zones, which condition is pronounced in Egyptian cotton. The zone of vegetative branches extends from the third to the tenth node; this is followed by a "transition zone" or "zone of rudimentary branches," of two or three nodes "at which the buds remain dormant, or the branches are extremely short or abortive." The "zone of fruiting branches follows from about the thirteenth node to the tip of the plant."

Underground Stems.—The cotton plant may produce underground stems. These arise from the same grooves from which lateral roots come. At first, these subterranean shoots are gall-like. Later, they attain various sizes.

Leaves.—The leaves have a regular spiral arrangement. The most common phyllotaxy in the cotton plant is three-eighths. This is the normal arrangement in all pure strains of Upland and Sea Island species and other natives of tropical America that are related. It is pointed out that with "the advance of acclimatization, the leaf arrangements are varied by frequent examples of one-third and two-fifths spirals" . . . Egyptian-Upland hybrid plants may have a one-third, two-fifths, or five-thirteenths arrangement. The phyllotaxy is one-third in Asiatic cottons. However, when Asiatic species are crossed, the hybrid plants may show a two-fifths or three-eighths arrangement. Leaf arrangement is similar on main stem and vegetative branches, but on fruiting branches the leaves are in two alternate rows; this latter condition is brought about by a twisting of the joints, each

being made up of the united filaments of the stamens. The filaments are thread-like and exserted. The anthers are one-celled, and each is dehiscent into two halves, by a semicircular opening.

Ovary (Fig. 213).—This has three to five cells or "locks." As a rule, the style is long, thus bringing the stigmas above the stamens. In Upland varieties, however, the style is usually shorter than the stamens. There are as many stigmas as there are cells in the ovary.

Pollination, Fertilization, and Development of Fruit.—Both cross- and self-fertilization may occur in cotton. Bees may be necessary in those varieties in which the style is long, bringing the stigmas above the anthers. Floral nectaries, at the base of the calyx on the inner side, are reached from within the corolla by long-tongued bees and butterflies. This is enabled by the failure of the petals to overlap at the base, thus leaving gaps through which the insect may protrude its tongue.

The seeds retain their attachment to the placenta until lint begins to develop, when their connection is broken through the absorption of the seed stalk, and the mechanical pressure of growing lint. Hence, the seeds come to occupy a position in the center of the cavity. Fiber begins to develop first at the apex of the seed.

Fruit.—The cotton fruit (Fig. 213) is a leathery capsule loculicidally dehiscent by three to five valves. The mature capsule is called a "boll." It varies in shape: subglobose, oval, or ovate-acuminate. The number of cells or "locks" is three or four in Sea Island and Egyptian varieties, and four or five in Upland sorts.

Seeds.—There are numerous seeds in each "boll." Seeds vary in shape: subglobose, ovate, or subovate.

Fiber.—The cotton fiber or hair is a simple extension of an epidermal cell of the seed coat. As a rule, there are two kinds

of hairs on the seed: (1) long hairs—lint or commercial fiber ("staple") and (2) short hairs or fuzz. The fuzz may be white, green, or brown in color. Some varieties produce no fuzz; hence when the seed is "ginned," it is left naked. Fuzzy-seeded varieties usually possess an abundance of long fibers. A high percentage of lint usually indicates small seed. In some varieties, the lint may form 34 per cent. or more of the seed.

Distribution of Seed Hairs.—Lint and fuzz are mixed together over the entire seed surface in Upland cottons. In Egyptian sorts, fuzz is limited to the ends of the seeds, with long fibers between the two patches. The lint at the tip of the seed in some Upland cottons is longer than that at the base.

Fiber Differences.—The fibers of Upland cotton are 1.8 to 2.5 centimeters long, and abundant; those of Sea Island are 2.5 to 4 centimeters long, but the yield is not as great as in the preceding species.

The following table is taken from Monie:

	Average length of staples in inches	Average diameter of staples in inches
Sea Island	1.61	0.000640
New Orleans	1.02	0.000775
Texas	1.00	0.000763
Upland	0.93	0.000763
Egyptian	1.41	0.000655

Form and Structure of Fiber.—Young cotton fibers are circular in cross-section. As they increase in length, the walls become thinner, and the fiber takes on a flattened ribbon-like appearance. The thickness of the walls becomes greater when the boll opens, due to the rapid consolidation of the liquid cell contents, which become deposited on the inner walls. The deposition is irregular, hence the twisting of the fiber. This twisting is a characteristic of the cotton

fiber. The twist is not necessarily in one direction throughout its length; there may be a reversal here and there.

The fiber is uniform in diameter for about three-fourths of its length, and then tapers gradually to a point. At the point, it may be perfectly cylindrical and solid. The hair cavity or lumen takes up about two-thirds of the entire breadth. Immature fibers or unripe fibers may show no evidence of internal structure, but are smooth, straight, and flat. "Kempy" fibers or "dead cotton" are such that are normal in structure a portion of their length, and have the appearance of immature and overripe fibers for another portion. The quality of fiber depends largely upon the number and regularity of twists, and upon its length and fineness. The mature cotton fiber is almost pure cellulose.

Cotton Fibers Distinguished from Other Common Textile Fibers.—There are two chief ways of distinguishing textile fibers, by microscopical examination and by chemical reactions. The cotton fiber is a flat, ribbon-like band twisted in a characteristic manner. The flax fiber is a straight, untwisted, cylindrical fiber, with peculiar transverse markings at intervals along its length. Hemp fibers resemble those of flax, but they may be distinguished from the latter by the peculiar forked ends which are nearly always exhibited, whereas flax fibers never show this character. All wool fibers possess characteristic overlapping scales. The silk fiber is smooth, structureless, transparent and quite regular in diameter.

There are many ways of distinguishing the fibers by observing their reactions to various chemicals. The following short key will illustrate a few of their characteristic reactions.

Dissolves in caustic potash.
- An alkali solution of the fiber treated with lead acetate colors fiber black, *Wool.*
- The above treatment does not color the fiber, *Silk.*

Does not dissolve in caustic potash.
- With iodine and sulphuric acid the fiber swells and becomes green, *Hemp.*
- With iodine and sulphuric acid the fiber swells and becomes blue.
  - Immerse fiber in concentrated sulphuric acid for two minutes, wash in water, treat with dilute ammonia, dry—fiber forms a gelatinous mass soluble in water, *Cotton.*
  - With above treatment, fiber is not altered, *Linen.*

Species.—Watt, in his great work, describes 42 distinct species and varieties of *Gossypium*. A number of them are known only in the wild state. *Gossypium*, as a genus, is indigenous to tropical regions. It is now grown under cultivation to the 40° latitude on either side of the equator.

Watt divides the wild and cultivated cotton plants of the world into five "sections," as follows:

Section I. Species with a Fuzz but no Floss.—"Wild species (never recorded as met with under cultivation), distributed from the western coast tracts and islands of America to Australia." Here are included *G. sturtii, davidsonii, klotzschianum, robinsoni, darwinii, tomentosum, drynarioides, harknessii,* and *stocksii*. The bracteoles are free, extrafloral nectaries absent, the fruit small, and the rather large seeds have a fuzz but no lint.

Section II. Fuzzy-seeded Cottons with United Bracteoles.—"One or perhaps two members of this section have been recorded as met with in a wild condition, the others are undoubted cultivated plants derived very possibly from four specific types—*G. arboreum, G. nanking, G. obtusifolium,* and *G. herbaceum.*" Most of these are Asiatic and African cottons. The bracteoles are united below, the claws of the petals are purple, and the seeds are covered with both fuzz and lint. Watt is strongly of the opinion that *G. arboreum var. neglecta*, was at an early date introduced into the United States, the form being known as "Okra." Its cultivation was abandoned, however.

G. nanking is the "Chinese cotton" of commerce, also known as "Siam cotton" or "Nankin cotton." It is "cultivated in China, Japan, the Malaya, Siam, Burma, India, the northwest Himalaya, Persia, Central Asia, to the Celebes; less abundantly in Madagascar, Arabia, and Africa."

G. obtusifolium is an oriental species that occurs both wild and cultivated in India and Africa. *Var. wightiana* is the most valuable Indian cotton.

G. herbaceum is not known to occur as a wild species anywhere, although Watt is of the opinion that it is indigenous to North Arabia and Asia Minor. In 1621, it was brought to the United States, and for a time cultivated, ut was finally replaced by the more desirable West Indian cottons. *G. herbaceum* is considered to be the first cotton cultivated in Europe. Watt believes that it still survives as an Upland cotton of the United States, though "mostly in a state of hybridization with G. hirsutum." Cook regards our Upland cottons as belonging to *G. hirsutum.*

Section III. Fuzzy-seeded Cottons with Free Bracteoles.—These are American and, in one case, African species. Here belong *G. mustelinum, punctatum, hirsutum, palmerii, fruticulosum, schottii, lanceolatum, microcarpum, peruvianum,* and *mexicanum*. *G. mustelinum* is a native of Brazil and Colombia. *G. punctatum* is native to southern United States, West Indies, and northern Africa. It exists in a state of cultivation in various sections. Watt considers *G. hirsutum* as "only a cultivated state of *G. punctatum*" . . . In this country, however, the Upland cottons are all considered as offsprings of *hirsutum* (Fig. 214). *G. palmerii, fruticulosum* and *lanceolatum* are Mexican

species. *G. schottii* is from Yucatan, and is known as the "split-leaved" cotton. *G. microcarpum*, known as Ashmouni cotton and Red Peruvian cotton, grows in Mexico, northern South America, Africa, and Malaya. It is cultivated. *G. peruvianum* is the Peruvian or Andes cotton. Watt regards many of the Egyptian cottons as races or hybrids of this species. *G. mexicanum* probably originally came from Mexico. Watt says: "I am convinced that

FIG. 214.—American upland cotton (Gossypium hirsutum). (*After Watt.*)

the best Upland cottons would be more correctly described as cultivated states of this plant (*G. mexicanum*), rather than as forms of *G. hirsutum*." He considers many of our Upland or short staple cottons as hybrids of *G. mexicanum* and *G. hirsutum*, sometimes with the characters of the one predominating, sometimes with those of the other. The long staple Upland series, chief representatives of which are Allen, Peeler, Simms and Sunflower, are also hybrids, with *hirsutum* characters dominant.

Section IV. Naked-seeded Cottons with the Bracteoles Free or Nearly so and Glands Conspicuous.—This section includes both Old- and New-World forms. The seeds are naked or nearly so, and the lint is easily removed. There is always some fuzz on the seed at the apex, hence they are not absolutely

FIG. 215.—Sea Island cotton (Gossypium barbadense). (*After Watt.*)

"naked." To this section belong *G. taitense, purpurascens, vitifolium, barbadense*, and *brasiliense.*

G. taitense is the wild cotton of Polynesia. It is not cultivated. *G. purpurascens* is known as Bourbon, Porto Rico, and Siam cotton. It is an important cultivated species. *G. vitifolium,* the vine-leaved cotton, has furnished a number of valuable cultivated types in Egypt, Antilles, etc. It is closely related to *G. barbadense. G. barbadense* (Fig. 215) includes the Sea Island cottons of America and Egypt. Watt believes that Sea Island cotton

is a modern development, not indigenous to Barbados or any of the West Indian Islands, but probably from somewhere in South America. He says that "it is highly probable the modern stock is a hybrid." The Sea Island cottons proper which have been grown with the greatest success on the islands off the coast of Carolina and Georgia are referred to *G. barbadense* var. *maritima*. *G. brasiliense* is indigenous to South America. It is cultivated extensively and is known as "Chain, Kidney, Stone, Brazillian, Guiana, Essequibo, Berbiche, Bahia, Pernambuco, and Coton-pierre cottons." This group is no longer of great commercial importance.

Section V. Naked-seeded Cotton with Bracteoles Quite Free and Floral Glands Absent.—Only one species, *G. kirkii*, belongs to this. It is from East and Central Africa, and is not cultivated. The lint is easily removed from the seed.

Wild Cottons.—Wild cottons all have a *red-colored*, hairy coating on the testa. There may be fuzz only, or both fuzz and lint, or lint alone. Cultivated cottons have a long *white* lint, in both fuzzy-seeded and naked-seeded forms. Sea Island cottons have the least fuzz of all cultivated forms. White lint may be regarded as brought about by cultivation. The appearance of rust-colored fuzz or lint may be regarded as a tendency to revert to the ancestral type.

The reddish tint of wild cottons is due to an aggregation of colored particles in the central core of the fiber.

American Cottons.—American authorities place the cottons of the United States into two species: *G. hirsutum*, American Upland cotton, and *G. barbadense*, Sea Island cotton. It has been noted above, however, that Watt claims that our Upland cottons are hybrids between *G. hirsutum* and *G. mexicanum*. Ninety-nine per cent. of the cotton crop in the United States is Upland.

The most important distinction between these two species is in staple length. The fibers of Upland cotton are from 1.8 to 2.5 centimeters long, those of Sea Island 2.5 to 4 centimeters long. The yield of the former is greater but the quality not so fine. The flowers are white, turning red on the second day of blooming in Upland cotton, but yellow with

a purple-red spot at the base of each petal in Sea Island cotton. The latter is limited to a small area along the coast of South Carolina, Georgia, and Florida.

Types and Varieties.—Upland is the chief American cotton. It has been divided by Duggar into a number of "groups" as follows:

1. *Big Boll Group.*—Plants vigorous and stocky; limbs strong, usually two in number; fruiting branches strong, varying from short to long; bolls large, 45 to 68 of them yielding a pound of cotton; four to five locules; seeds large, very fuzzy, white to brownish gray or greenish in color; lint 20 to 30 millimeters long. Examples: Triumph, Rowden, and Texas Storm-proof.

2. *Long Staple Group.*—Plants slender; limbs two or three, sometimes absent, slender; fruiting branches also slender; bolls small to medium, long, slender, tapering to a point, three-, four-, or five-loculed; seeds medium to large, sometimes partly naked, but usually densely covered with a brownish-gray fuzz; lint 30 to 45 millimeters long, percentage low. Examples: Allen, Griffin, Express, and Webber.

3. *Cluster Group.*—Plants slender, often tall, limbs heavy, one to several; fruiting branches very short-jointed, causing the bolls and leaves to be in clusters, apparently two or three from each node; bolls small to medium, four- to five-loculed; seeds small to medium, fuzzy, gray to brownish- or greenish gray; lint short, soft, and of good strength. Examples: Jackson, Dickson.

4. *Semi-cluster Group.*—This group resembles closely the preceding. The bolls are borne singly but close together. It is probably a hybrid group with strong cluster tendencies. Examples: Hawkins.

5. *Rio Grande or Peterkin Group.*—Plants slender; limbs one to several; fruiting branches slender, long-jointed; bolls very small to medium, three-, four-, or five-loculed; seeds very small to medium, nearly smooth, dark-colored, sometimes covered with a short fuzz; lint medium in length, percentage large. Examples: Peterkin, Texas Wood, Rio Grande.

6. *King or Early Group.*—Plants small and slender; limbs one to three or more; fruiting branches medium to short-jointed, but long in proportion to plant height; bolls small, three-, four-, or five-*loculed* seeds small to medium, fuzzy, greenish or brownish gray; lint short to medium, 33 to 35 per cent. of seed. Earliest American cottons. Examples: King, Simpkins and Broadwell.

7. *Long-limbed Group.*—Plants large; limbs long with long joints; bolls and seeds medium to large; lint percentage low; fuzz of various shades. Examples: Petit Gulf, Peeler, Hagaman. This group is of little importance.

8. *Intermediate Group.*—This group includes a number of varieties with characters so badly mixed up as to make it impossible to refer them to any particular group. It is well known that our American cottons hybridize quite readily under field conditions. Examples: Breeden, Boyd, Roby, Tucker.

Environmental Relations.—Cotton is a tropical plant. The upper latitudinal limit of cotton growing in this country is about coextensive with the summer (June, July and August) isotherm 77°F. The plant is extremely sensitive to low temperatures, and even a light frost in the fall stops its development. It seldom matures in less than 180 days. The plant not only requires a high temperature, but also one not subject to fluctuations, as such conditions cause premature ripening. After the plant has attained its vegetative growth, the ripening of fruits and seeds is favored by cooler nights than prevailed up to that period.

Light, frequent showers which permit of an abundance of sunshine favor the development of the plant. Too much rain is liable to stimulate an excessive development of vegetative growth at the expense of fruit formation.

Upland cottons are adapted to a variety of soils, while the Sea Island varieties are best suited to soils with low water-retaining capacity, and of medium fertility.

Picking and Ginning of Cotton.—Cotton is picked by hand, and loaded into wagons. This labor is performed almost exclusively by negroes. The seed cotton is removed from the wagon by means of a suction fan, and carried over a single gin or battery of gins. It passes into chutes over the feeders, and is then fed evenly to the gin saws, where the lint and seed are separated. The seeds are carried by a screw conveyor to the seed house or seed bin. The lint cotton is led from the gin saws through a flue to the condenser. Here it is cleaned, smoothed out into sheets or bats, wrapped and tied into bales. The usual size of a cotton bale is 27 by 54 inches and the weight about 500 pounds. Sea Island cotton is ginned in a type known as the roller gin, as the fiber is injured by the saw gin type.

When seed cotton comes to the gin, it contains boll hulls and trash. This is usually removed by passing the seed

cotton through a cleaner, before it reaches the gin saws. The boll hulls are frequently used for fuel.

Bleaching of Cotton.—The object of this process is to remove the waxy coating of the fiber, in order that it may absorb the dyestuffs easily, and also remove all the impurities adhering to the fiber. Cotton may be bleached in any stage of its manufacture, in the loose state, as yarn, or as cloth. The process of bleaching is the most thorough and is carried further in the making of print cloth than in the preparation of other grades of cloth, as the cloth must be absolutely white and free of all impurities in order that the printing colors can be applied properly, and the patterns appear distinct and sharp. The cloth is first *singed* to remove loose fibers and lint, and leave a clear even surface. It is then taken through the *boiling out* process, in which the cloth is given one or more boilings in caustic soda in order to remove the waxy, fatty and pectic substances from the fiber. After a thorough *washing* in water, the cloth is treated with a bleaching powder solution. The *souring* process follows, in which the cloth by treatment with a dilute solution of sulphuric acid is rendered free of the lime compounds and undecomposed chlorine derivatives. Another thorough washing then follows, after which the cloth is given a finish, the nature of which depends upon the use to which it will be put.

Uses of Cotton.—The *lint* is spun into thread or yarn, and woven into all sorts of fabrics. The finer threads are made from Sea Island cotton, while ordinary threads and yarns are from long staple upland cotton. The short lint or fuzz, known as "linters," which is not removed in ginning, is taken from the seeds and made into coarse twine, carpets, and batting.

Cottonseed Hulls.—These are used in the manufacture of paper and fiber board from which are made gear wheels,

trunks, etc. The hulls are also utilized as fuel and fertilizer, and as a cattle food.

Cottonseed Oil.—This is one of the most valuable products of the cotton plant. The oil of the seed is in the embryo. After the seed coats are removed, the embryos ("meats"), are cooked for twenty to thirty minutes to melt the oil, and to drive off some of the water. The oil is then extracted under pressure. A ton of seed yields about 40 gallons of crude oil. Various grades of cottonseed oil are secured by different processes of refining and filtering.

Cottonseed oil is now produced in large quantities in this country. The United States exported 33,673,000 gallons of the oil in 1921. It is used for edible purposes, appearing on the market usually under some such name as "sweet nut oil," "salad oil," or "table oil." It may be utilized as an adulterant of such oils as peanut and olive oils. However, it is fully as nutritive as olive oil and is actually preferred by many. It is used sometimes in the manufacture of soaps. It is also extensively employed in the manufacture of "oleomargarine," and butter and lard substitutes. "Cottolene" is composed of refined cottonseed oil and beef suet.

Cottonseed Meal.—Cottonseed meal is the ground cake left after the oil is pressed from cotton seed. It is now used extensively as a feed, although formerly it was considered of little value. United States produces annually several hundred thousand tons of cottonseed meal, much of which is exported. The death of animals sometimes associated with its use is due to a toxic substance, *gossypol*. Cottonseed kernels are now rendered less toxic by extracting the gossypol with ether, or with ether and alcohol; or by treating the meal with an alcoholic solution of an alkali, thus oxidizing the gossypol and rendering it non-toxic. Cottonseed meal is also highly prized as a fertilizer.

Guncotton.—This is a powerful explosive made by treating cotton or some other form of cellulose with nitric acid or sulphuric acid. Military guncotton is a mixture of very

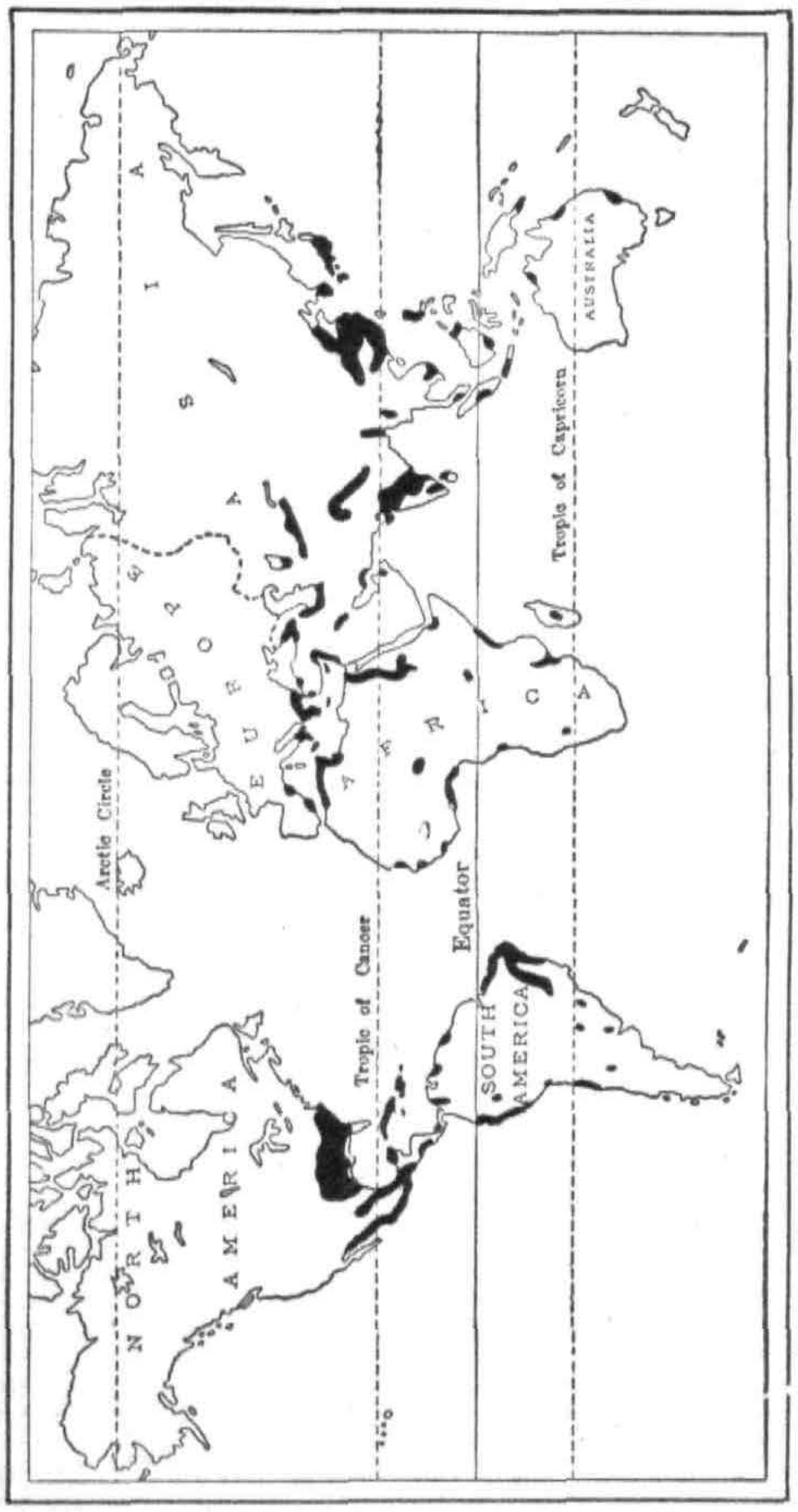
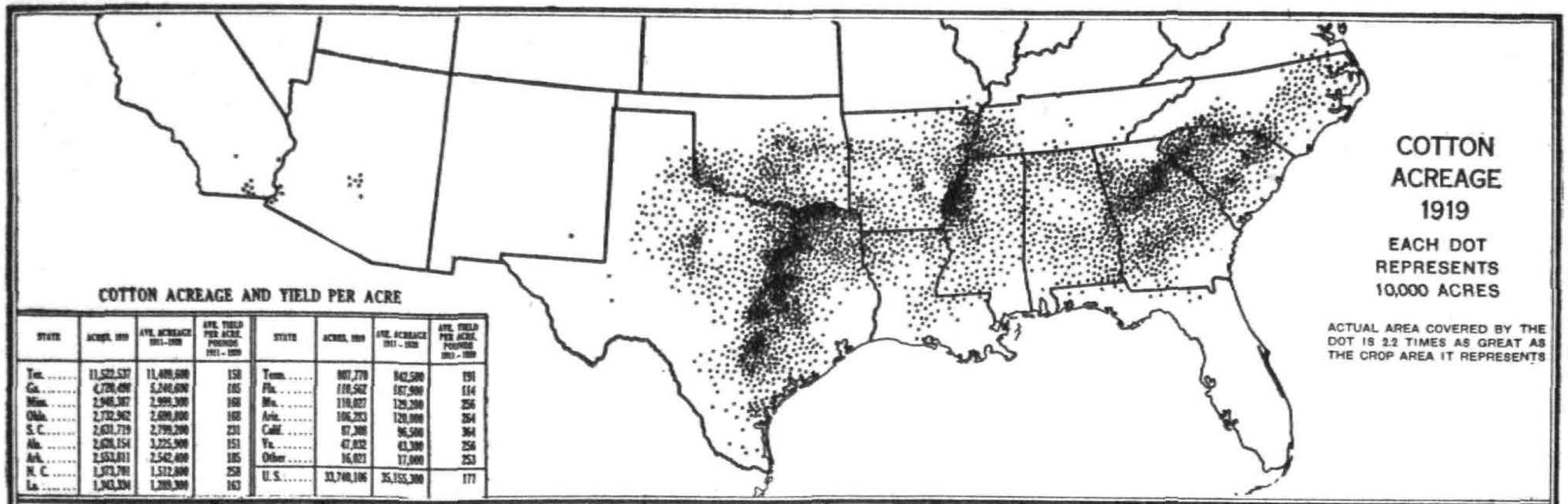


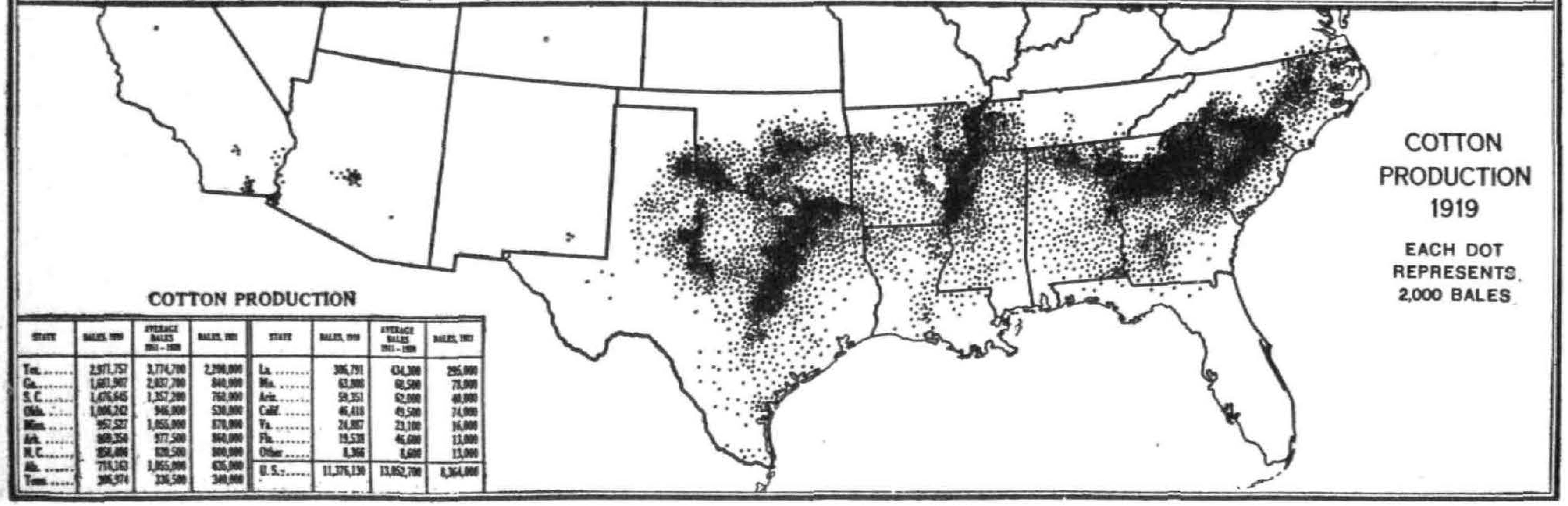
FIG. 216.—Cotton-producing regions of world. (*From Essentials of Geography Second Book. Copyright, 1916, by Albert Perry Brigham and Charles T. McFarlane. American Book Company, Publishers.*)

highly nitrated cellulose nitrates. Less highly nitrated guncotton is soluble in alcohol and ether, and such soluble guncotton is used in the manufacture of collodion, celluloid, etc. Celluloid is made by subjecting a mixture of guncotton,



COTTON ACREAGE AND YIELD PER ACRE

STATE	ACRES, 1919	AVE. ACREAGE 1911–1920	AVE. YIELD PER ACRE, POUNDS 1911–1920	STATE	ACRES, 1919	AVE. ACREAGE 1911–1920	AVE. YIELD PER ACRE, POUNDS 1911–1920
Tex.	11,522,537	11,400,500	158	Tenn.	907,770	942,500	191
Ga.	4,720,498	5,240,600	185	Fla.	110,562	187,900	114
Miss.	2,940,387	2,999,300	168	Mo.	110,027	129,200	256
Okla.	2,732,962	2,690,000	168	Ariz.	106,253	120,000	264
S. C.	2,631,719	2,799,200	231	Calif.	87,308	96,500	364
Ala.	2,628,154	3,225,900	151	Va.	47,832	43,300	256
Ark.	2,553,811	2,542,400	185	Other	16,021	17,000	253
N. C.	1,373,781	1,512,800	258	U. S.	33,740,106	35,155,300	177
La.	1,343,334	1,289,300	163				



COTTON PRODUCTION

STATE	BALES, 1919	AVERAGE BALES 1911–1920	BALES, 1921	STATE	BALES, 1919	AVERAGE BALES 1911–1920	BALES, 1921
Tex.	2,971,757	3,774,700	2,290,000	La.	306,791	434,300	295,000
Ga.	1,681,907	2,037,700	840,000	Mo.	63,000	68,500	73,000
S. C.	1,476,645	1,357,200	760,000	Ariz.	59,351	62,000	40,000
Okla.	1,006,242	946,000	530,000	Calif.	46,418	49,500	74,000
Miss.	957,527	1,055,000	870,000	Va.	24,887	23,100	16,000
Ark.	869,350	977,500	860,000	Fla.	19,530	46,600	13,000
N. C.	858,406	820,500	800,000	Other	8,366	8,600	13,000
Ala.	718,163	1,055,000	635,000	U. S.	11,376,130	13,052,700	8,364,000
Tenn.	306,974	336,500	340,000				

camphor, and other minor substances to great pressure. Collodion is a solution of guncotton in ether and alcohol.

Importance and Production of Cotton.—Cotton is the most important fiber plant in the world. The clothing of a great majority of people is cotton. The largest of manufacturing enterprises are concerned with the production of cotton goods. Cotton is the most important article of world trade. The world's crop in 1910 is estimated at 22,433,269 bales, as compared with 15,893,591 bales in 1900. In 1914, the United States led in cotton production, with 16,134,930 bales. British India ranked second with an output of 4,238,494 bales.

HIBISCUS ESCULENTUS (Okra, Gumbo)

Description.—Okra or gumbo is a stout, annual plant. The *stems* are cylindrical and usually rough-hairy. The *leaves* are large, heart-shaped, three- to five-lobed, and with very prominent veins; the lobes are coarsely toothed. The solitary, showy *flowers* arise in the leaf axils; they are subtended by numerous, narrow, involucral bracts; the calyx is five-cleft; there are five large yellow petals; the stamens form a column which is five-toothed at the apex, and is anther-bearing along its entire length; the *ovary* has five cells, each of which has several ovules; there are five style branches, each tipped by a capitate stigma. Okra is regularly cross-pollinated by insects, chiefly bumble bees. The *fruit* is a pod with five longitudinal ribs; the seeds are large and kidney-shaped.

Geographical.—The original home of okra is tropical Africa. It is now introduced into many civilized countries, and grown as a vegetable with particular success in the warmer ones.

Types.—Beattie divides the varieties of okra into three types: (1) *Tall green*, (2) *dwarf green*, and (3) *lady finger*.

Each of these is further divided into long-podded and short-podded sorts. Plants of the "lady-finger" type are much lighter in color than those of the other two types. Tall green okras are 4 to 8 feet high, dwarf green sorts about 1½ to 3½ feet high, and lady-finger varieties close to 3 feet high.

Uses.—Okra is used chiefly in soups. Not infrequently the young seeds are cooked. When the pods are very young and tender, they are cooked and served as a salad. A fiber used in the manufacture of paper is sometimes made from both stems and mature pods. In some countries the pods are dried, and in this form kept for winter use. The seeds are sometimes used as a substitute for coffee.

References

BALLS, W. L.: The Sexuality of Cotton. Yearbook Khediv. Agr. Soc. Cairo, 1905.

BEATTIE, W. R.: Okra: Its Culture and Uses. U. S. Dept. Agr. Farmers' Bull. 232: 1–16, 1905.

BOWMAN, F. H.: Structure of the Cotton Fiber. Manchester, England, 1881.

BROOKS, E. C.: The Story of Cotton. Chicago, New York, and London, 1911.

COOK, O. F., and MEADE, R. M.: Arrangement of Parts in the Cotton Plant. U. S. Dept. Agr. Bur. Plant Ind. Bull. 222: 1–26, 1911.

Dimorphic Leaves of Cotton and Allied Plants in Relation to Heredity. U. S. Dept. Agr. Bur. Plant Ind. Bull. 221: 1–59, 1911.

COOK, F. O. MCLACHLAN, ARGYLE, and MEADE, R. M.: A Study of Diversity in Egyptian Cotton. U. S. Dept. Agr. Bur. Plant Ind. Bull. 156: 1–60, 1909.

DUGGAR, J. F.: Descriptions and Classification of Varieties of American Upland Cotton. Ala. Agr. Exp. Sta. Bull. 140: 1–104, 1907.

EVANS, W. H.: Botany of Cotton. U. S. Dept. Agr. Office of Expt. Stats. Bull. 33: 67–80, 1896. Contains a Bibliography of Cotton.

FLATTERS, A.: The Cotton Plant: Its Development and Structure and the Evolution and Structure of the Cotton Fiber. London and Manchester, 1906.

MEADE, R. M.: Methods of Securing Self-pollination in Cotton. U. S. Dept. Agr. Bur. Plant Ind. Cir. 121: 29: 30, 1913.

MONIE, HUGH: The Cotton Fiber, Its Structure, Etc. Manchester and London, 1890.

REED, E. L.: Leaf Nectaries of Gossypium. Bot. Gaz., 63: 229–231, 1917.
STEUCKART, C.: Die Baumwolle, ihre Herkunft, ihre Verwendung, ihre Geschichte, und Bedeutung. Leipsic, 1914.
TYLER, F. J.: The Nectaries of Cotton. U. S. Dept. Agr. Bur. Plant Ind. Bull. 131: 45–54, 1908.
Varieties of American Upland Cotton. U. S. Dept. Agr. Bur. Plant Ind. Bul. 163: 1–127, 1910.
WATT, G.: The Wild and Cultivated Cotton Plants of the World. New York and London, 1907.

CHAPTER XXXIV

UMBELLIFERÆ (Carrot Family)

Stems and Leaves.—All the common representatives of the carrot family are herbs. A very few are shrubs or trees. The *stems* are usually hollow. The *leaves* are alternate, sometimes opposite at the base of the stem, and as a rule pinnately or ternately compound. In a few genera (as *Bupleurum*, *Hydrocotyle* and *Oxypolis*), they are simple. In *Sanicula*, they are digitately parted or lobed. In the carrot, fennel, and others, the leaves are decompound. The petioles are frequently swollen and broadened at the base and partly sheathe the stem. There are no stipules, or, if present, are very small.

Inflorescence and Flowers.—The inflorescence is nearly always an umbel, either simple or compound, but occasionally a head (as in *Eryngium*). The umbel is so characteristic of this group of plants as to suggest the name "Umbelliferæ" (literally meaning umbel-bearing). In a compound umbel, the smaller groups of flowers are designated umbellets. The umbel as a whole is commonly subtended by an *involucre*, the umbellets by an *involucel* (little involucre). When the inflorescence has an involucre, it is said to be involucrate; when it has involucels, it is involucellate.

The *flowers* (Fig. 218) are small, mostly regular, perfect or polygamous, and pentamerous. In some instances, the outer flowers of the umbel are irregular, the petals pointing outward being somewhat larger than those pointing inward. The *calyx*, when present, forms a tube wholly adnate to the ovary; the limb of the tube is absent, or divided into five

inconspicuous teeth. The *corolla* consists of five separate petals, attached to the base of the calyx tube; the tips of the petals are usually turned in, and emarginate or two-lobed. There are five *stamens*, curved inward in the young flower, with filiform filaments and versatile anthers. The single,

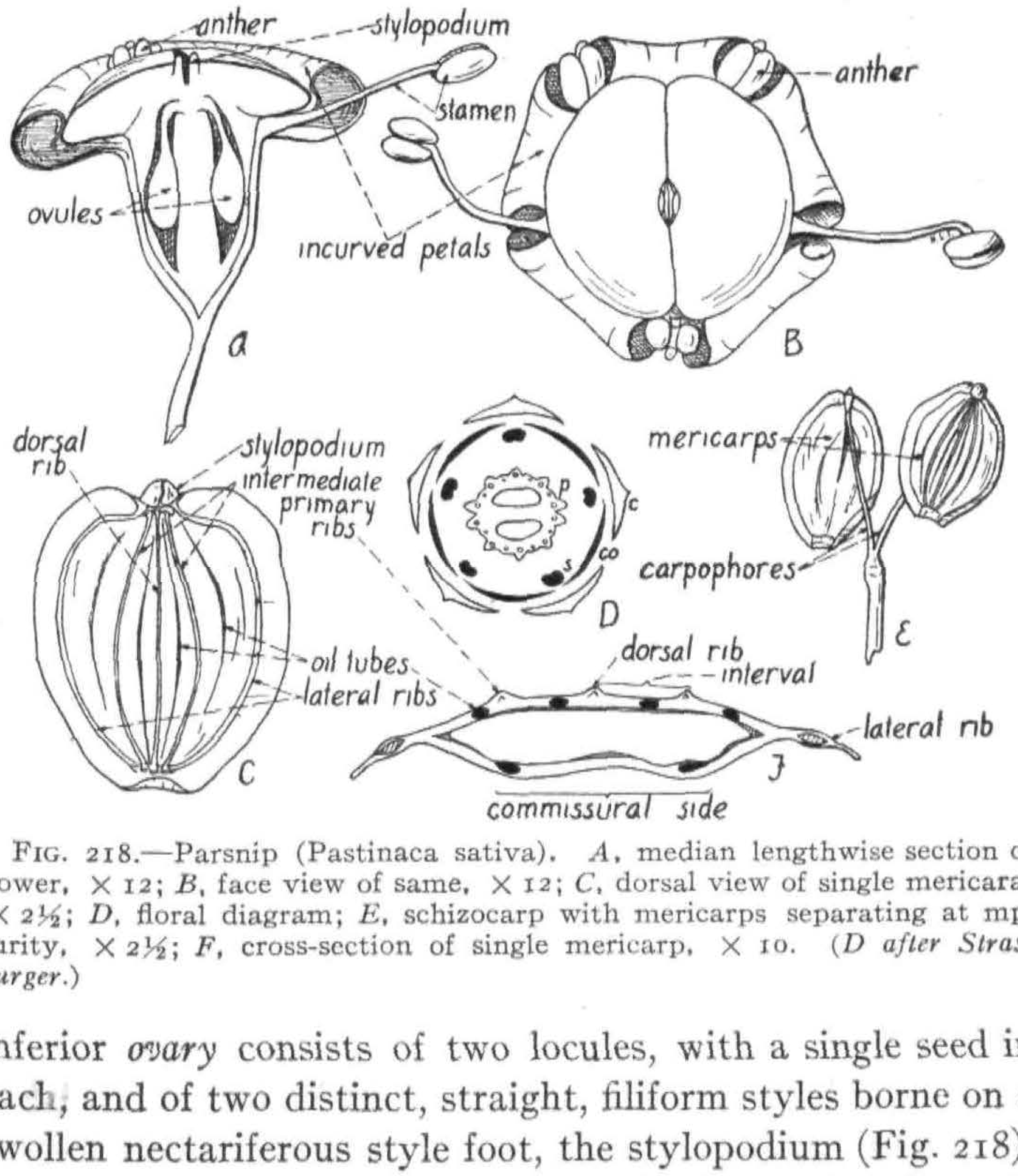


FIG. 218.—Parsnip (Pastinaca sativa). *A*, median lengthwise section of flower, × 12; *B*, face view of same, × 12; *C*, dorsal view of single mericara- × 2½; *D*, floral diagram; *E*, schizocarp with mericarps separating at mp. turity, × 2½; *F*, cross-section of single mericarp, × 10. (*D after Strasburger*.)

inferior *ovary* consists of two locules, with a single seed in each, and of two distinct, straight, filiform styles borne on a swollen nectariferous style foot, the stylopodium (Fig. 218). In some genera (as *Apium*, celery), the stylopodium is inconspicuous or wanting. The umbellifers are usually insect-pollinated. Protandry is common.

Fruit.—The umbelliferous *fruit* (Fig. 218) is very characteristic. It is termed a *schizocarp*, *i.e.*, a dry fruit of two

carpels, these separating at maturity along the midline or *commissure* into two one-seeded halves—the *mericarps*. Each individual carpel or mericarp is indehiscent. The two mericarps remain attached for a while after splitting by a forked stalk, the *carpophore* (Fig. 218, E). At the summit of the fruit is a swollen nectary, the *stylopodium*, giving rise to two short, persistent, usually outwardly curved styles. Each mericarp bears, on the outside, five longitudinal membranous or corky ribs, the *primary ribs*. These are modifications of the pericarp; each encloses vascular bundles. In some cases there is one *secondary rib* in each of the four *furrows* or *grooves* between the primary ones, thus makig in many instances nine ribs (five primary, four secondary) to each half of the nature fruit. Within the grooves, as is best seen by a cross-section of a mericarp (Fig. 218, F), are oil tubes (vittæ), running lengthwise of the fruit. These tubes contain secretions of balsams, resins, and volatile oils, which impart to the fruit its characteristic odor and taste. The fruit may be bristly (as in carrot) or smooth (as in parsnip, and many others). The bristles may cover the fruit (as in *Sanicula*), or be confined to the ribs (as in carrot). Oil tubes are sometimes obsolete or obscure (as in *Conium*, *Hydrocotyle*, *Washingtonia*). If distinct, they are solitary (as in parsnip) or several (as in *Angelica*, *Cymopterus*). There are usually two or more oil tubes on the commissural side, that is, on the side that is contiguous with the adjoining mericarp.

The *fruit* is either flattened *laterally* (at right angles to the commissure), or flattened *dorsally* (parallel to the commissure), or in some instances not flattened at all (terete or nearly so). The one *seed* in each carpel completely fills the whole cavity and is usually adnate to the pericarp; the inner seed faces may be concave or flat. There is considerable oily endosperm present in the seed. The small embryo is

imbedded in the endosperm near the hilum. The fruit is of greater taxonomic importance than any other portion of the plant. Usually, it is necessary to have the mature fruit before an accurate determination can be made of a species in hand. Keys to the genera and species are largely based upon fruit characters.

Geographical.—The carrot family is one of north temperate regions, not being well represented in the tropics. According to Britton and Brown, there are close to 1,600 species in about 170 genera.

Key to Genera of Economic Importance

Fruit bristly, *Daucus* (carrot).
Fruit not bristly.
  Fruit strongly flattened dorsally, with lateral ribs more or less prominently winged (Fig. 218, F), *Pastinaca* (parsnip).
  Fruit not strongly flattened dorsally, usually more or less laterally flattened (Fig. 222, B).
    Stylopodium conical.
      Involucre wanting; leaves pinnately compound.
        Flowers white, *Coriander* (coriander).
        Flowers yellow, *Fœniculum* (fennel).
      Involucre present; leaves ternately compound, *Carum* (caraway).
    Stylopodium flat or wanting, *Apium* (celery and parsley).

DAUCUS CAROTA (Carrot)

Root and Stems.—The common carrot is usually a biennial, sometimes, however, running to seed the first year. During the first season of growth, there is a storage of food in the enlarged hypocotyl and prominent tap root, both of which become fleshy, forming the so-called "carrot." Four longitudinal rows of secondary roots are given off from the tap root. The roots are much thinner and woodier in the wild form of the carrot than in cultivated forms.

In a cross-section of the "carrot" the following tissues may be seen, from the outside to inside: (1) periderm (skin); (2) cortex and phloem; (3) cambium; (4) central region

(wood and pith). A good carrot is one with a proportionately large cortex and phloem, because in these most of the sugar is stored. During the second season of growth, a rough, hispid stem, 2 or 3 feet high, and with spreading branches, is sent up from the "crown" of the carrot.

Leaves.—All the leaves are decompound (doubly compound). The lower ones are two- to three-pinnate, the segments linear or lanceolate, dentate, lobed or pinnatifid, the upper ones smaller and less divided.

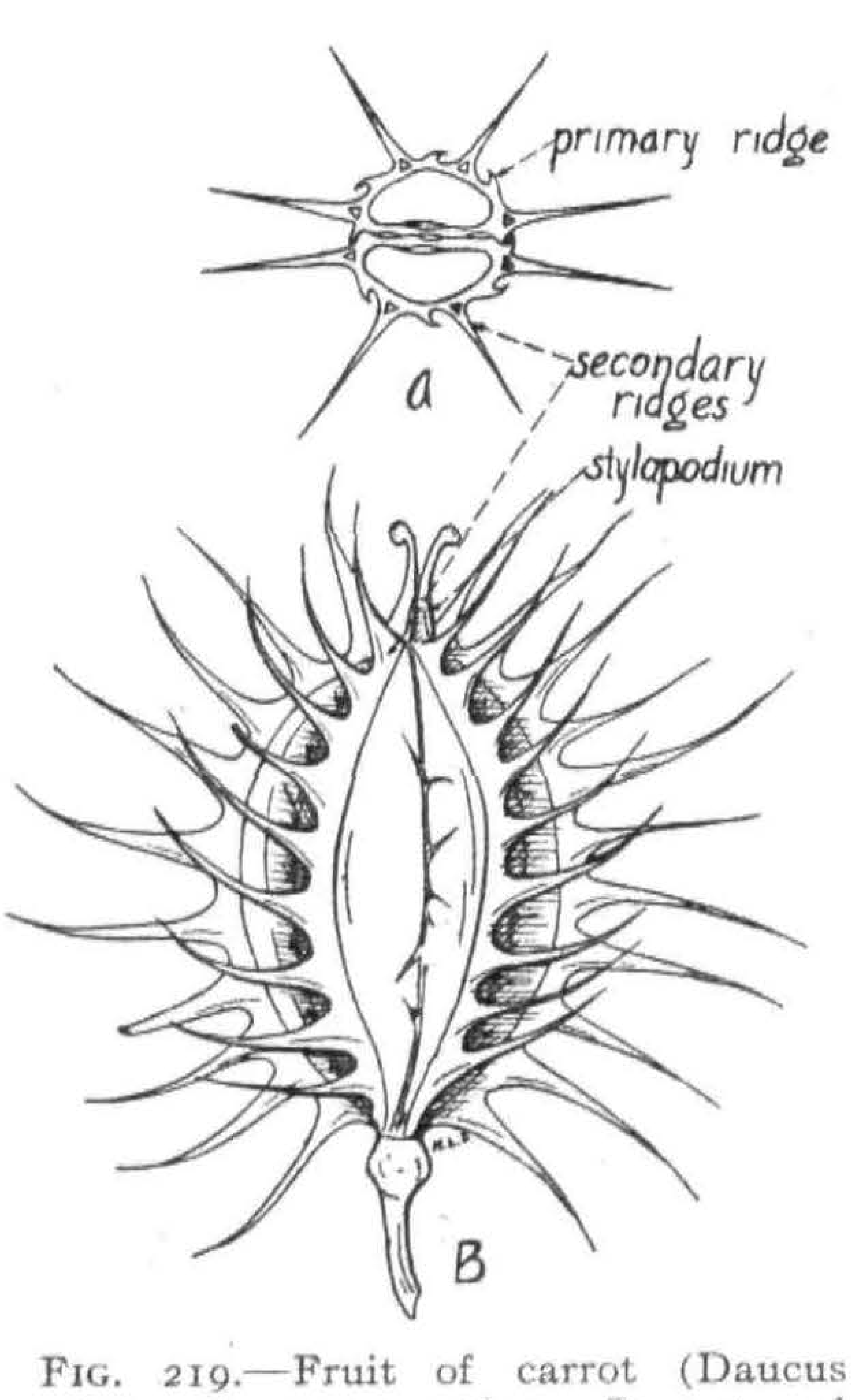


FIG. 219.—Fruit of carrot (Daucus carota). *A*, cross-section; *B*, external view. (*A*, *after Sargent.*) *B* × 10.

Inflorescence and Flowers.—The inflorescence is a compound umbel. At maturity, the outermost pedicels bend inward, the whole forming a structure resembling a bird's nest. The involucral bracts are long, and cleft into a number of narrow lobes. The involucels, at the bases of the umbellets, are made up of entire or toothed lobes. The flowers are small and white, the central one of each umbel often purple, or all the flowers are pinkish. The calyx teeth are lacking. There are five petals, obovate, and with the tips turned in.

Fruit and Seed—The fruit (Fig. 219) is oblong and dorsally flattened. The five primary ridges of each carpel bear long hairs, and each of the four secondary ridges bears

about ten long spines, at the ends of which are three or four hooked hairs. The *oil tubes* (vittæ) are solitary in the intervals, that is, under the secondary ribs, and two are on the commissural side of each mericarp. The seed is flattened dorsally, and the face plane or slightly curved.

Geographical.—The wild form of *Daucus carota* is a native of Europe and Asia. It has become common throughout North America, in many places proving a troublesome weed. All the cultivated forms of carrot are considered to be derived from this one wild form.

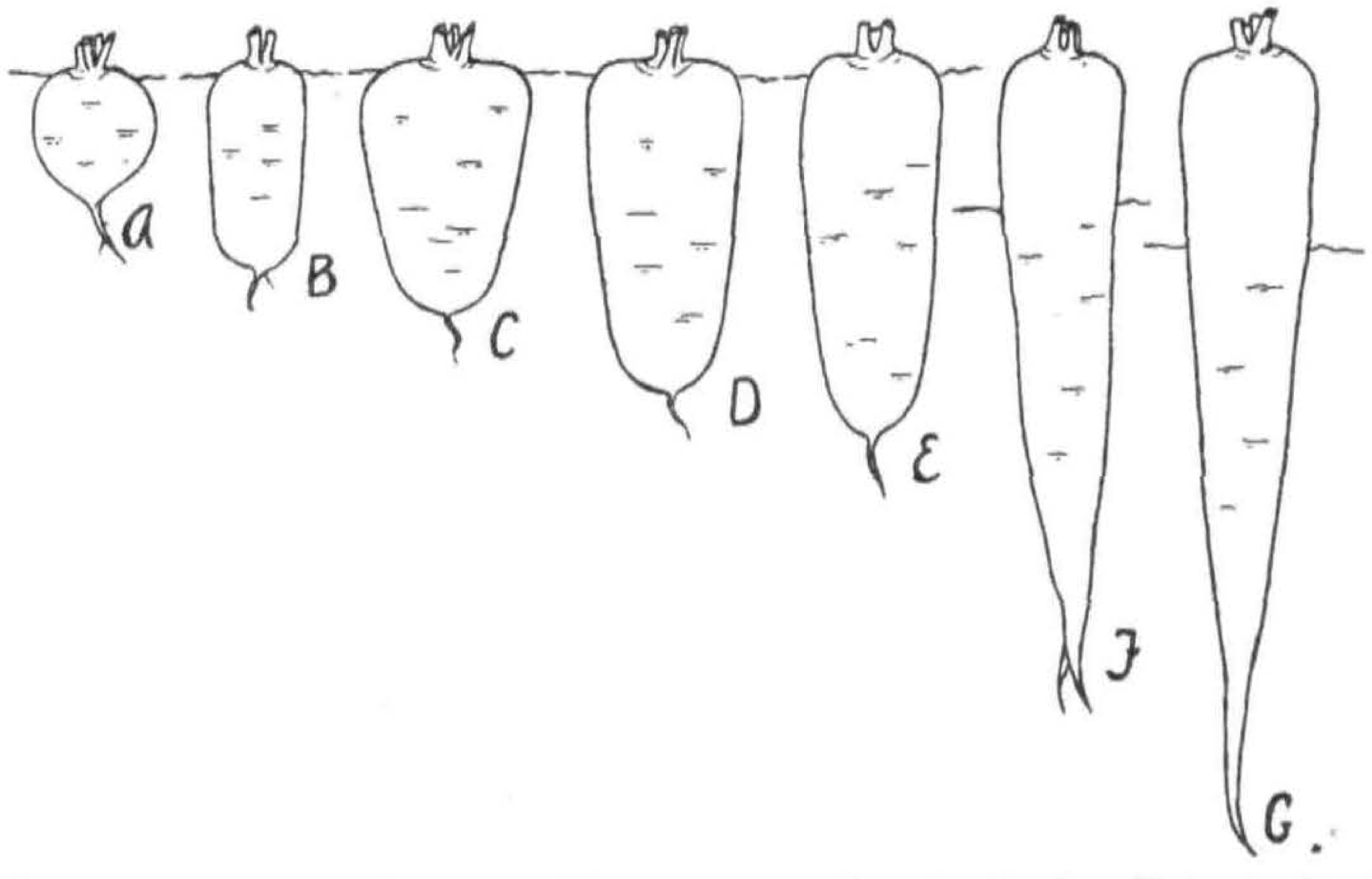


FIG. 220.—Types of carrots (Daucus carota). *A*, Garden Ball; *B*, Early Scarlet; *C*, Oxheart; *D*, Chantenay; *E*, True Danvers; *F*, Saint Vallery; *G*, Long Orange.

Varieties.—There are numerous varieties of carrots varying as to size, shape, color, and quality. As to shape of the vegetable, varieties may be divided into two groups (Fig. 220).

1. Roots distinctly pointed, tapering (Long Orange, Saint Vallery).

2. Roots blunt at the tip, not pointed (Early Scarlet Horn, Ox-heart, Chantenay, Stump-rooted Half Long Red).

The roots may be white (Large White, White Vosges, White Belgian), red (Carentan), orange or orange red (Early French Forcing Oxheart, Long Orange), or purple-violet (some Egyptian and Spanish varieties).

Uses.—Medium-size carrots, particularly those with yellow or orange flesh, are used as a table vegetable and for the seasoning of soups and stews. The larger, coarser varieties, such as Large White, Large Yellow Belgian, Danvers and White Vosges, are grown for feeding stock during the winter season. The yellow coloring matter, carotin, is sometimes extracted from the roots and used for coloring butter.

PASTINACA SATIVA (Parsnip)

Roots and Stems.—The parsnip is of either annual or biennial duration. When grown from seed, a fleshy hypocotyl and tap root are first formed; these constitute the "parsnip" vegetable. In the wild form, the root and hypocotyl are thin, tough, and woody. During the second season, a branching stem is sent up to a height of from 2 to 3 feet. The tall, erect stems are grooved, smooth or somewhat downy pubescent, and become hollow.

Leaves.—The lower and basal leaves are petioled, pinnately compound, the thin segments ovate or oval, lobed, incised or dentate. The upper leaves are sessile, much smaller than the lower, and not so deeply lobed. The terminal leaflet of each leaf is usually three-lobed.

Inflorescence and Flowers.—The flowers (Fig. 221) are in broad compound umbels usually with 7 to 15 main "rays," each terminated by a small umbellet. There are no involucres and involucels in the parsnip, thus differing markedly from the carrot. The flowers are yellow. The calyx teeth are very small or absent, the petals incurved and small, the stylopodium depressed, and the ovary inferior.

Fruit and Seed.—The fruit (Fig. 218) is broadly oval and much flattened dorsally. The dorsal and two intermediate primary ribs are thread-like, while the lateral ribs are expanded into broad, flat wings, with those of the two meri-

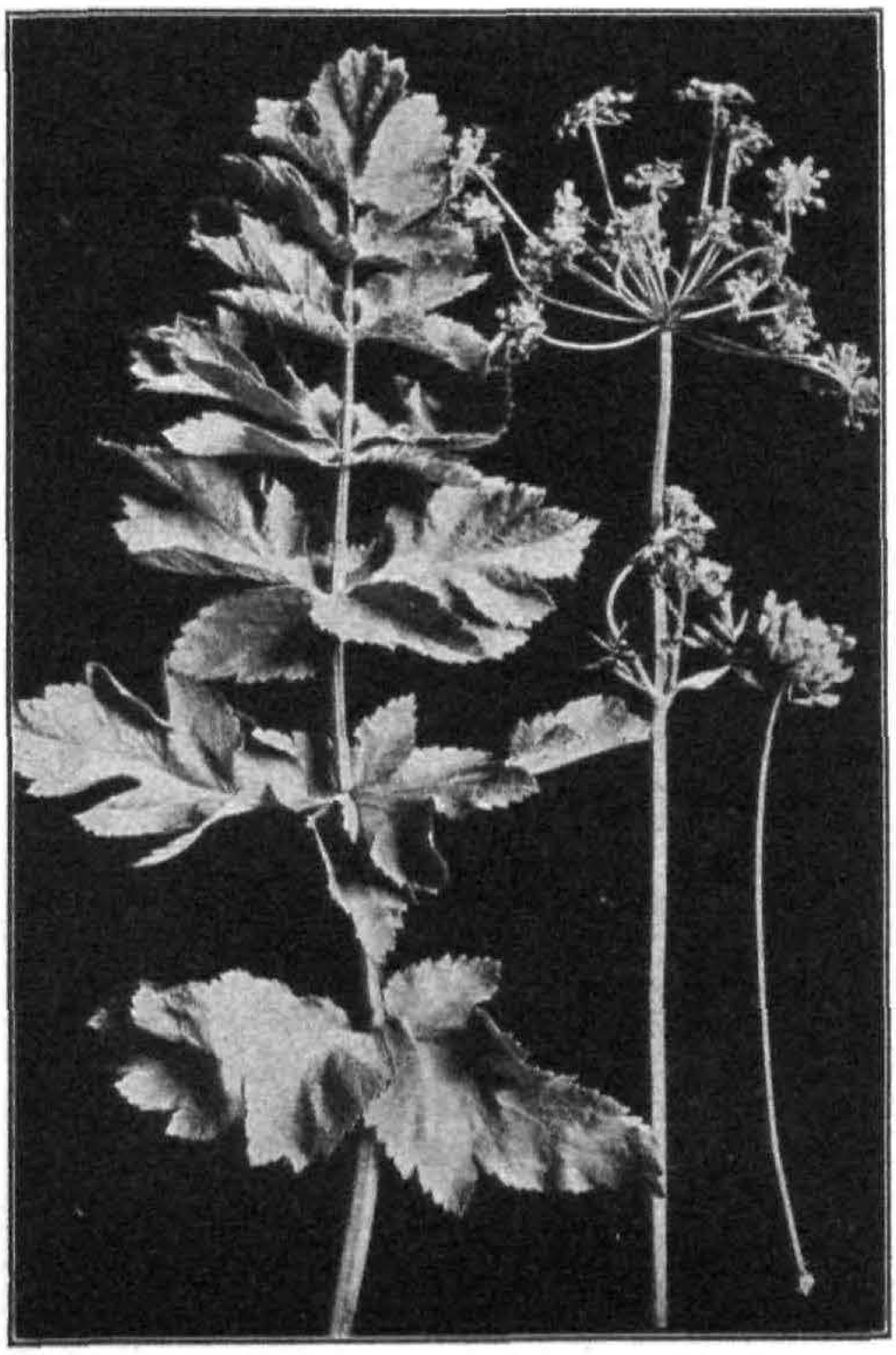


FIG. 221.—Leaf and inflorescence of parsnip (Pastinaca sativa).

carps contiguous. The oil tubes are solitary in the intervals; there are four on the dorsal side and two to four on the commissural side. The olive-green seeds are flattened dorsally. The seeds are very short-lived.

Geographical.—The wild parsnip, *Pastinaca sativa*, from which our cultivated varieties are derived, is a native of Europe. This wild form has

become naturalized in many sections of North America, occurring as a weed along roadsides and in waste places.

Varieties.—There are comparatively few parsnip varieties. Probably the most popular sorts are the Guernsey and Hollow Crown. In both of these, the crown is concave.

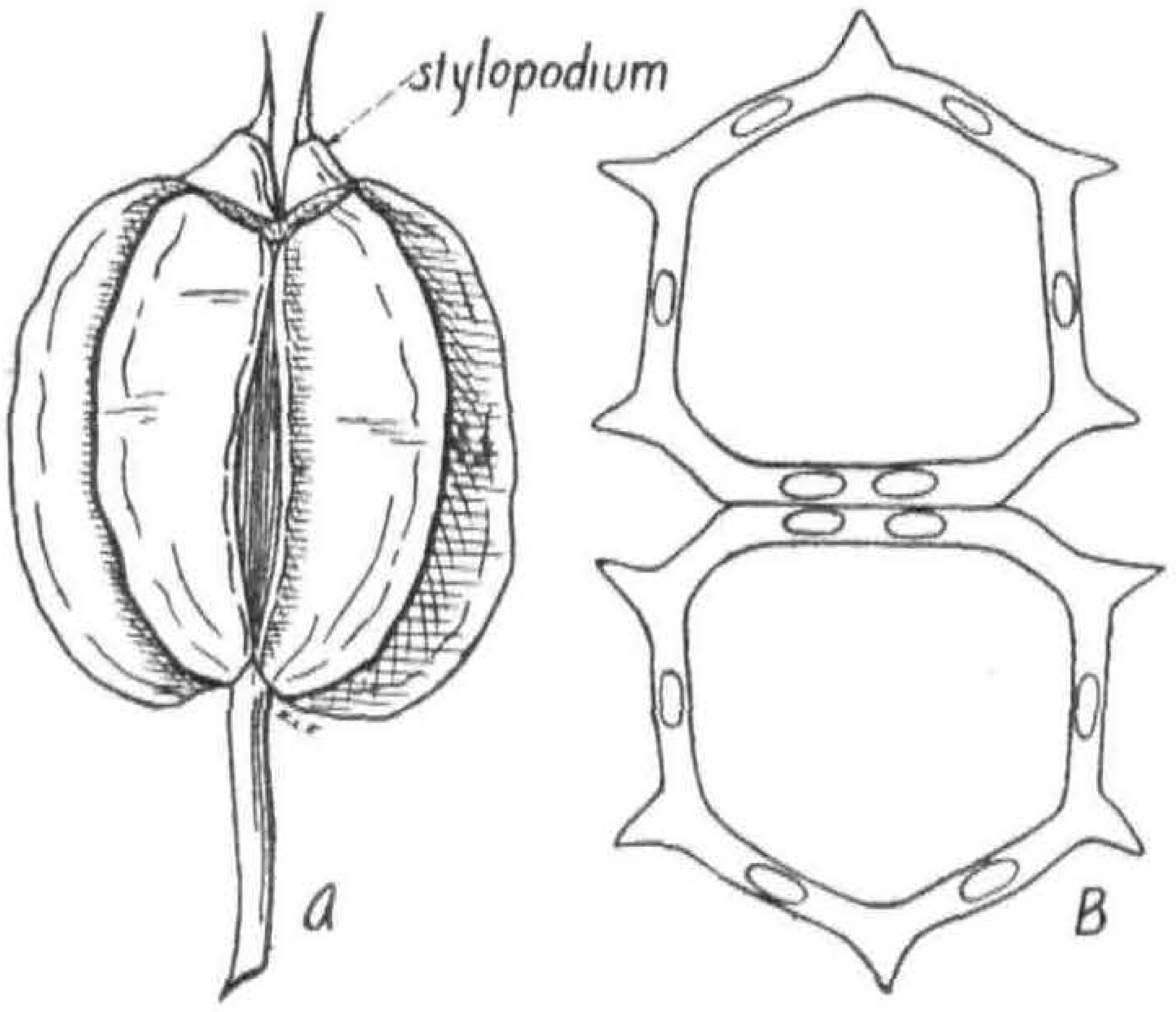


FIG. 222.—Celery (Apium graveolens). *A*, schizocarp, external, × 15; *B*, diagrammatic cross-section of schizocarp, × 20.

APIUM (Celery and Parsley)

Generic Description.—Members of this genus are annual or perennial herbs with pinnately divided *leaves*. The white or greenish *flowers* are in compound umbels. The involucre and involucels may be present or wanting. The calyx teeth are absent. As in many umbellifers, the petals are turned in at the tip. The *fruit* (Fig. 222) is flattened laterally, broader than long, smooth or covered with protuberances. The mericarps have pronounced corky ribs; the oil tubes are solitary in the intervals, with two on the commissural side.

Geographical.—There are about 18 species in this group, distributed chiefly in the Eastern Hemisphere. There are two well-known cultivated species (parsley and celery) both of which are natives of Europe, and an indigenous species, *Apium leptophyllum*. These three species are distinguished in the following key.

KEY TO PRINCIPAL SPECIES OF APIUM

Flowers greenish-yellow, *Apium petroselinum* (common parsley).
Flowers white.
Leaf segments broad, *Apium graveolens* (celery and celeriac).
Leaf segments narrow, *Apium leptophyllum* (fine-leaved marsh parsley).

APIUM PETROSELINUM (Parsley)

Description.—Common garden parsley is a biennial, the first season throwing out a dense whorl of radical *leaves* that are bipinnate, triangular in outline, and with the segments ovate, and dentate or incised. During the second season, there is sent up an erect, highly branched *stem*, 1 to 3 feet high. The upper leaves are also bipinnate, but the segments are linear-oblong and entire.

The *inflorescence* is a compound umbel with linear involucral bracts and awl-shaped involucellate bractlets. The *flowers* are greenish-yellow. The *fruit* is ovate, smooth, and with pronounced ribs.

When large parsley seed is used the plants from them have larger and earlier foliage and are more capable of renewing the tops after being cut back than plants from small seed.

Varieties.—As to leaf characters, there are two types of parsley:

1. *Plain Parsley.*—Leaves plain, not curled.
2. *Double Curled, Dark Moss-curled, Fern-leaved Parsley.*—Leaves curled.

The turnip-rooted or Hamburg parsley is a type bearing a small, fleshy root, which is the edible part of the plant.

APIUM GRAVEOLENS (Celery and Celeriac)

Description.—This species is either annual or biennial in habit, most commonly the latter. When grown from seed, there is formed, in the cultivated sorts, a clump of *leaves* with thick, fleshy leaf stalks. The leaf stalks are the edible portions of common celery. If the plants have been stunted

or set back in their development, seed stalks may be sent up the first season. Of course, in celery growing, the "*seeders*" are undesirable and every effort is made to prevent their appearance. Normally, however, seed stalks are sent up from the short rootstock the second season. This stem is erect, glabrous, and 1 to 3 feet high. The leaves are pinnately compound with three to five oval, coarsely toothed or incised leaf segments. The small white *flowers* are in umbels. Involucre and involucels are small or wanting. The *fruit* is oval, flattened laterally, and has corky ribs. The oil tubes are solitary in the intervals and two in number on the commissural side.

Geographical.—*Apium graveolens*, the wild form giving rise to our cultivated celery and celeriac, is a native of Europe. In eastern United States, it has escaped from cultivation, and it is said that in the salt marshes of California it has become naturalized.

Types and Varieties.—There are two types into which the cultivated celery has been modified by breeding and selection: (1) *common celery*, with enlarged, tender, edible leaf stalks, and (2) *celeriac*, "German celery" or turnip-rooted celery (*A. graveolens var. rapaceum*), with a fleshy, turnip-like rootstock, 2 to 4 inches long. These rootstocks constitute the edible portion of the plant (Fig. 223).

There are two general types of the common celery: (1) *self-blanching varieties*—quick-growing, very tender, easily-blanching sorts, especially adapted for fall and early winter use (Golden Self-blanching, White Plume). Blanching (see page 250) is secured by keeping the leaf stalks away from the light; the leaf blades, however, are permitted to grow in the light, so that the processes of food-making proceed in a normal manner, and the stalk is not stunted. Chlorophyll is formed only in those parts of the plant exposed to the light directly. Boards, paper or earth are placed about the stalks to exclude the light.

(2) *Green or winter varieties*—not as quick-growing or easily blanched as those of the preceding type and, furthermore, with better keeping qualities when stored for the winter (Giant Pascal, Boston Market, Winter Queen).

FIG. 223.—Celeriac (Apium graveolens). (*After Vilmorin.*)

All cultivated varieties of celery require cool weather and plenty of moisture for their best development; they are intolerant of excessive heat. Celery culture is carried on with the greatest success on reclaimed muck soils in regions with a cool climate.

Uses.—Celery is grown principally for the thick, fleshy leaf stalks. The leaves are also used for garnishing and seasoning, and the seeds are used for flavoring salads and soups. The fleshy root of celeriac is used as a flavoring or is stewed separately.

References

COULTER, J. M., and ROSE, J. N.: Monograph of the North American Umbelliferæ. Contr. U. S. Nat. Herb., 7. No. 1: 1–256, 1900.

CHAPTER XXXV

VACCINIACEÆ (Huckleberry Family)

This is a widely distributed family ccourring in tropical, temperate, and arctic regions. It is closely related to the heath family (*Ericaceæ*) which possesses such well-known plants as kinnikinic (*Arctostaphylos uva-ursi*), the creeping wintergreen (*Gaultheria*), American Laurel (*Kalmia*), Labrador tea (*Ledum*) *Azalea*, *Rhododendron*, and trailing arbutus (*Epigæa repens*). In the heath family, however, the ovary is superior instead of inferior as in the huckleberry family. There are two important genera from an agricultural standpoint, *Vaccinium* and *Gaylussacia*. The former genus includes a rather large number of species grown for their fruit; these take in the bilberry, blueberry, cranberry, huckleberry, and whortleberry. *Gaylussacia* spp. are known as tangleberry, blue huckleberry, and dangleberry. *Gaylussacia* may be distinguished from *Vaccinium* by its ten-celled ovary, with one ovule in each cell. In *Vaccinium* the ovary is four- to five-celled, or sometimes eight- to ten-celled by false partitions.

The plants belonging to this group are erect or prostrate shrubs or, in a few instances (*e.g.*, *Vaccinium arboreum*, the farkleberry) a small tree. Some South American species are epiphytic.

Leaves.—The leaves are simple, alternate, often thick and leathery and sometimes evergreen, and without stipules.

Inflorescence and Flowers.—The *flowers* are solitary in the leaf axils (as in *Chiogenes hispidula*, the creeping snowberry, or *Vaccinium membranaceum*, the thin-leaved bil-

berry), or in racemes (as in *Vaccinium virgatum*, southern black huckleberry, or *Vaccinium oxycoccus*, the European cranberry). The inflorescences of *Vaccinium* species are sometimes terminal and sometimes axillary. In all common species, except *Vaccinium atrococum*, the flowering shoots bear leaves, as is the case in the blackberry, raspberry and grape. The flower pedicels are usually bracted. The small *flowers* are perfect, sympetalous, and usually actinomorphic (Fig. 224). The *calyx* (Fig. 225) forms a tube, grown fast to the ovary, the limb (free portion) four- to five-lobed or four- to five-cleft, and either persistent or deciduous. The sympetalous *corolla* is divided into four or five lobes or very

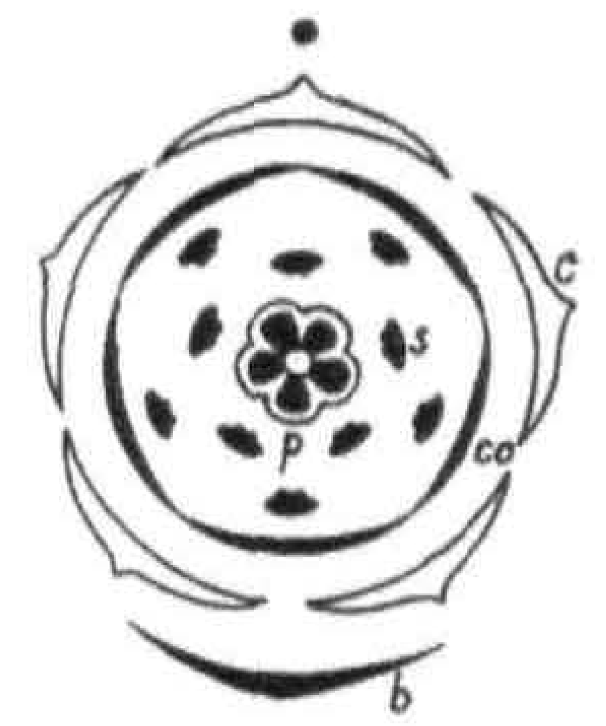


FIG. 224.—Floral diagram of Vaccinium.

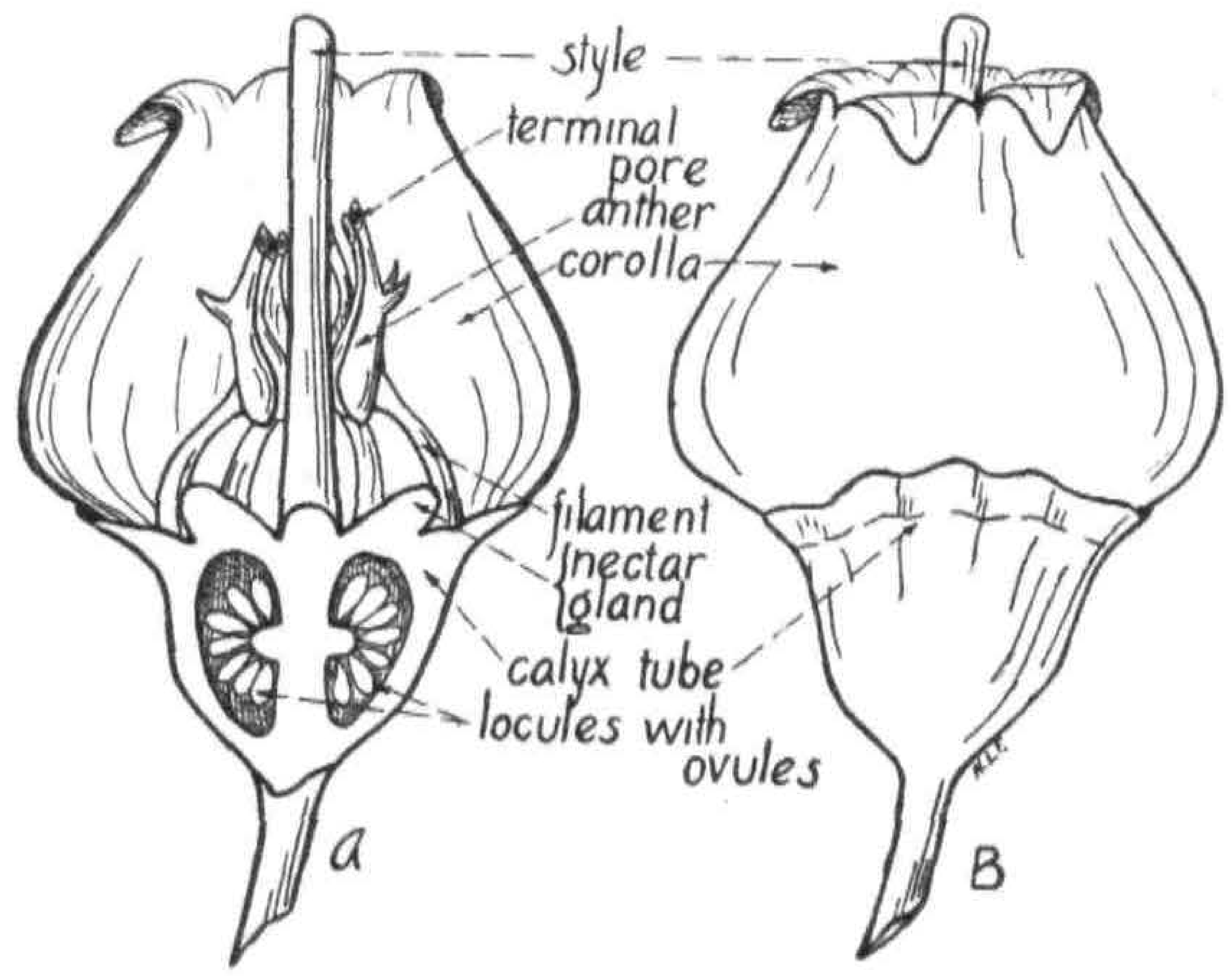


FIG. 225.—Flower of Vaccinium. *A*, median lengthwise section; *B*, external view.

rarely into nearly separate petals, as in the cranberries. The corolla may be either globe-shaped, bell-shaped, urn-shaped, or tubular. There are twice as many *stamens* as corolla lobes, and they are usually inserted at the base of the

corolla; the filaments are commonly flattened, short, and either free or united; the two-celled anthers are upwardly prolonged into tubes, and open by a terminal pore (Fig. 225). The *ovary* is inferior, four- to five-celled or eight- to ten-celled by false partitions, and has a filiform style, a small stigma, unmodified at the tip, four to five-lobed or four- to five-toothed, and one to several ovules in each locule.

Fruit.—The *fruit* is globular and either a many-seeded berry (as in *Vaccinium*) or drupe-like (as in *Gaylussacia*). The seeds are small, compressed, and have a bony seed coat, and a small embryo imbedded in a fleshy endosperm.

VACCINIUM

The representatives are shrubs or small trees. The leaves are leathery. The flowers are solitary or in short racemes. They have characters as described above under the family.

Pollination.—Coville describes the method of pollination in a blueberry. It is quite probable that this will hold true for most *Vaccinium* species. The bell-shaped flower is inverted, the 10 stamens hang downward and are shorter than the style. The flat filaments form a close circle about the style, being held together by the interlacing marginal hairs. When an insect visits the flower, the only easy way it can get at the nectar, which is situated at the base of the stamens on their inner side, next to the style, is to push its proboscis between the anther tubes. In this process, the mature pollen grains are shaken loose, and some of them stick to the insect's body, to be carried by it to flowers visited subsequently. The anther pores open inward. The stigma is top-shaped and the very apex is the only receptive portion. Hence the rim of the stigma just below the receptive surface, prevents the falling pollen from reaching this surface. In this way self-pollination is to a large extent prevented.

If pollen from the same plant is used in pollination, the fruit that is formed remains small and green, and later drops off. This fact serves to emphasize the need, in the propagation of blueberries by cutting, of making the plantation from cuttings of a number of different bushes.

Fruit.—The fruit is a many-seeded berry. It matures about two months after flowering. The berries are most commonly blue-black in color, although albino forms are known to occur. The calyx is permanently attached to the fruit. Berries may remain on the bushes a month or more after they have reached maturity without losing their flavor or firmness.

Geographical.—The genus is widely distributed in the northern hemisphere, mostly in North America and the Himalayas. It includes about 125 species, about 27 or more of which are native to North America.

KEY TO CHIEF FRUIT-BEARING SPECIES OF VACCINIUM

Fruit red in color.
- Stamens included, *V. vitis-idæa* (cowberry, mountain cranberry, foxberry).
- Stamens exserted.
  - Leaves ovate, acute at the apex; stems slender, creeping; berries globular, *V. oxycoccus* (small cranberry).
  - Leaves oval or oblong, obtuse or retuse at the apex; stems stout, creeping, with ascending branches; berries egg-shaped or oblong, *V. macrocarpon* (American cranberry).

Fruit blue or black in color.
- Plants low, seldom over 2 feet tall.
  - Leaf surfaces free of hairs.
    - Berries blue.
      - Leaves shining above, *V. cæpitosum* (dwarf bilberry).
      - Leaves not shining above, *V. vacillans* (low blueberry, blue huckleberry).
    - Berries black.
      - Flowers solitary in leaf axils, *V. myrtillus* (whortleberry, bilberry).
      - Flowers in groups in leaf axils.
        - Fruit with bloom, *V. angustifolium* (low blueberry).
        - Fruit without bloom, *V. nigrum* (low black blueberry).
  - Leaf surfaces hairy, *V. canadense* (Canada blueberry).
- Plants tall, 3 to 12 feet, and spreading.

Flowers solitary in leaf axils, *V. ovalifolium* (tall or oval-leaved bilberry).
Flowers in groups in leaf axils.
Fruit blue, *V. corymbosum* (high-bush blueberry, swamp huckleberry).
Fruit black, *V. atrococcum* (black blueberry).

GAYLUSSACIA (Huckleberry, Tangleberry, Dangleberry)

Description.—Members of this genus are shrubs with alternate and entire or finely toothed *leaves*. The inflorescence is a raceme. The small white or pink *flowers* are on two-bracteolate pedicels. The calyx tube is short, five-lobed or five-toothed, and persistent. The stamens are 10 in number, and their anthers open by terminal pores. The *fruit* is described as a berry-like drupe, or 10-celled drupe with 10 seed-like nutlets. The "seeds" are each covered with endocarp.

Geographical.—The genus is distributed throughout North and South America. It possesses about 40 species. There are five species of *Gaylussacia* growing in North America.

Key to North American Species of Gaylussacia

Leaves evergreen, finely toothed, *G. brachycera* (box-huckleberry).
Leaves deciduous, entire.
Fruit with a bloom, *G. frondosa* (blue huckleberry, tangleberry, dangleberry).
Fruit without a bloom.
Leaves 2 to 4 inches long, *G. ursina* (Carolina huckleberry).
Leaves 1 to 2 inches long.
Bracts small, deciduous, *G. resinosa* (black or high-bush huckleberry).
Bracts large, persistent, *G. dumosa* (dwarf or bush huckleberry).

Of the above species, *G. resinosa* is, as a rule, the common black huckleberry on the market. This species is a shrub, 1 to 3 feet high, with stiff branches, oval or oblong leaves that are very resinous when young, a few pink or red flowers and sweet, seedy, black fruit. It grows in sandy soil from Newfoundland to Georgia, westward to Kentucky and Manitoba.

CRANBERRIES

Some botanists place the cranberries in the genus *Oxycoccus*, separate from the blueberries, huckleberries and bilberries, which are included in the genus *Vaccinium*. In *Oxycoccus* the corolla is deeply four-cleft or four-divided, while in *Vaccinium* it is bell-shaped or cylindric and divided only at the very apex. We have placed all the cranberries in the genus *Vaccinium*. There are two principal species of

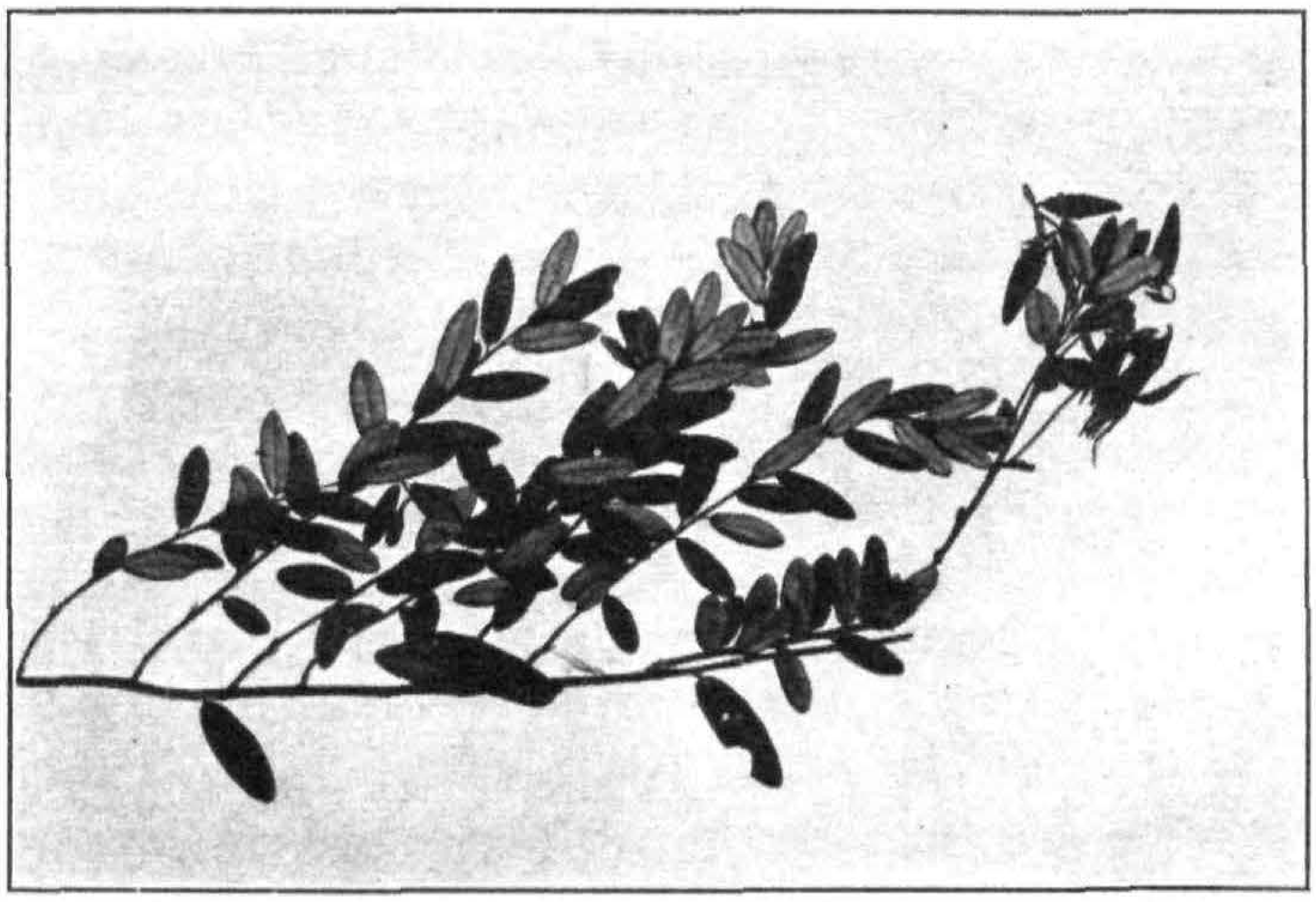


FIG. 226.—American cranberry (Vaccinium macrocarpon).

cranberries grown in America: American cranberry (*Vaccinium macrocarpon*) and the small cranberry (*Vaccinium oxycoccus*). These are distinguished in the key above. It seems that the appearance of the flower in the bud has probably suggested the name cranberry or "craneberry." Just before the flower opens, the pedicel, calyx and corolla resemble the neck, head, and bill of a crane.

Vaccinium macrocarpon (Large or American Cranberry).—This is a low, slender, creeping plant with oblong or oval

leaves, whitened beneath, and with rolled margins. The flowers are on short upright one-year-old shoots; they occur in very short clusters; the corolla is light pink. The berry is red, ovoid, oblong, or almost globular. At the summit of the fruit are four persistent, short calyx lobes, bent inward.

This species is found wild in boggy land in the northern part of the United States, adjacent Canada, south along the eastern coast to Virginia and North Carolina. It is also found in South America. It is the cranberry that is cultivated to a large extent in the cranberry centers in this country—Cape Cod, New Jersey, Wisconsin, Michigan and Minnesota. The cultivation of cranberries in the United States is practically confined to cool, moist boggy regions. Cranberries are grown in natural or artificial bogs, which are capable of being drained or flooded at will.

Types.—Corbett divides American cranberries into four groups, based upon fruit shape.

1. *Bell.*—These are the most popular and include such varieties as Early Black and Centennial.
2. *Bugle.*—Mathews, Howe, Centerville, Dennis.
3. *Olive.*—McFarlin's, Howes, Jumbo.
4. *Cherry or Spherical Cranberries.*—Early Red, Arpin, Makepeace.

Vaccinium oxycoccus (Small Cranberry).—This is the cranberry of the Old World. It is a slender, creeping plant with thin stems, 4 inches to 1 foot long, and with ovate, acute or acuminate leaves, dark green above, whitish beneath. The flowers are very similar to those in the preceding species. The berry is red, globular, four-celled, and often spotted when young; it is smaller than that of the American cranberry, although considered by some of superior quality.

The small cranberry is a native of alpine and subarctic regions of Asia, Europe and America. It is not cultivated in America to any great extent.

Vaccinium vitis-idæa (Mountain Cranberry).—This is a low evergreen shrub with creeping stems and thick, leathery leaves. The flowers are in short, terminal, one-sided clusters. The berries are dark red.

This plant grows wild from Massachusetts to Labrador, west to British Columbia and Alaska. Although not cultivated, the natives, particularly of Nova Scotia, gather large quantities of this wild cranberry and ship them to eastern markets.

HUCKLEBERRIES AND BLUEBERRIES

Both of the above names are applied to the fruit of species of *Vaccinium* and *Gaylussacia*. However, it is uncommon to see the name blueberry given to the fruit of *Gaylussacia* spp. These bear 10 seeds in each fruit, and although not as numerous as in the berry of *Vaccinium*, are more troublesome. There are two general types of blueberries: high-bush blueberries (*V. corymbosum*, and *V. atrococcum*), and low-bush blueberries (*V. canadense, V. angustifolium, V. nigrum*, and *V. vacillans*).

The common black huckleberry on the market is *Gaylussacia resinosa*. *Vaccinium angustifolium* is a rather common low-bush blueberry, while *V. corymbosum* is the species most desirable for cultivation.

References

COVILLE, FREDERICK V.: Experiments in Blueberry Culture. U. S. Dept. Agr. Bur. Plant Ind. Bull. 193: 1–100, 1910.

DAVIS, W. T.: High-bush Blueberries. Proc. Staten Island Assn. Arts and Sci., 2: 63–64, 1909.

CHAPTER XXXVI

OLEACEÆ (Olive Family)

Family Description.—This is a family of trees or shrubs. The *leaves* are opposite , exstipulate, and simple or pinnately compound. The *inflorescence* is a panicle, raceme, cyme or fascicle. The *flowers* are regular, and polygamous or diœcious; the small *calyx* is four-lobed, sometimes entirely absent; the regular *corolla* is four-parted, or of four distinct petals, or absent. There are two *stamens*, attached to the corolla or to the receptacle. The single *pistil* is compound, with a two-celled *ovary*, in each of which there are a few seeds, a short style, and capitate stigma; sometimes the style is absent. The *fruit* is either a capsule, samara, berry, or drupe.

Geographical, and Economic Importance.—There are about 21 genera and 500 species distributed widely in temperate and tropical regions. The most important representative is the olive (*Olea europœa*). Other well-known members of the family are the lilacs (*Syringa*), privet (*Ligustrum*), Jessamine (*Jasminum*) and ash (*Fraxinus*).

OLEA EUROPŒA (Olive)

Description.—The common olive is a small tree 20 to 25 feet high. All fruit is borne on two-year-old wood, and the same wood never bears twice. The lanceolate *leaves* are leathery, evergreen, entire, smooth, scaly, and arranged oppositely on the stem. The *flowers* occur in axillary racemes as a rule, although terminal inflorescences are more or less frequent. They are borne on wood of previous season's

growth. The flowers are usually imperfect. The small calyx is four-toothed, the corolla four-cleft, white or whitish,

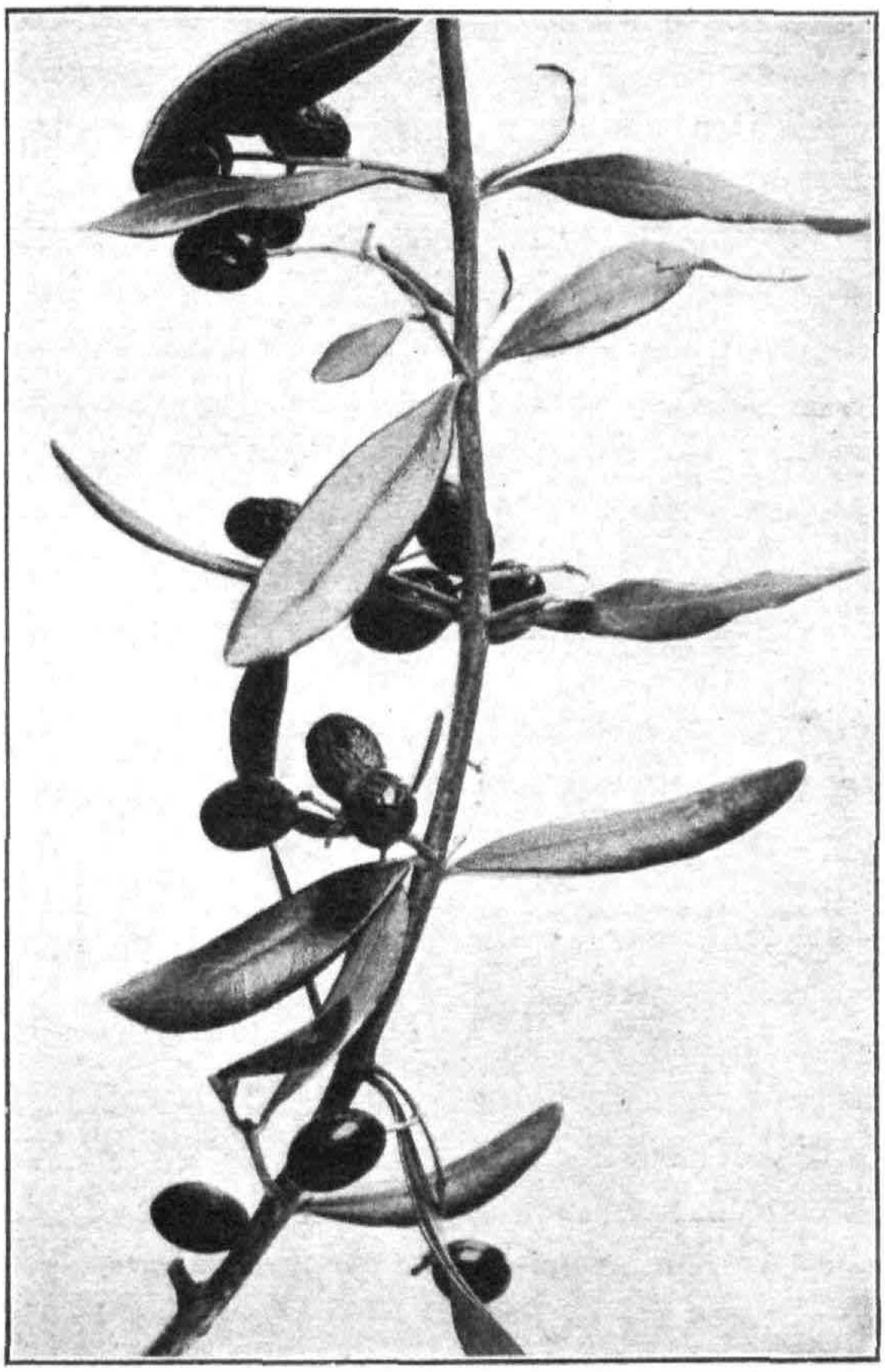


FIG. 227.—Olive (Olea europœa). Branch and fruit. (*From Calif. Agr. Exp. Sta.*)

the stamens two, and the pistil one. The *fruit* is a purplish drupe.

The olive is probably a native of the Mediterranean region. Its cultivation in this country is confined almost entirely to

the warm, dry portions of California. The olive requires a mean annual temperature of 57°F., and it is claimed that at no time should the temperature go below 14°F. The olive is one of the well-known cultivated plants of antiquity. Today it is found wild in the countries bordering the Mediterranean, but it is not known positively whether or not it is indigenous to this region or has escaped from cultivation.

Seed Germination.—If olive seeds do not receive some treatment before planting, they will not germinate for a year or more. This delay in germination is due to the thick, stony covering, and to the oil present which inhibits water penetration. The delay in germination has been overcome, in part, by various means, such as soaking in warm water, soaking in alkaline or acid solutions, cracking the stones, and clipping the apex of the seed. The last method appears to be the best.

Propagation.—The olive is very easily reproduced vegetatively; in fact, cuttings of any kind will grow. For propagative purposes use may be made of green cuttings with the leaves on, of chips from old trunks, of young or old limbs, and even of *knaurs*. Knaurs are knots or excrescences formed upon the trunks of old trees. When limbs 2 or 3 inches in diameter are used, they are cut into lengths of 1 or 2 feet, each split lengthwise, and planted horizontally with the bark up. Sprouts readily arise from the section of trunk, and such sprouts may be allowed to continue their growth where they are, or be made into green cuttings.

Uses.—Olives are eaten either in the green or ripe state. They are usually "pickled," and left whole, or "stuffed." Olive oil is an important commercial product. The best quality of olive oil, known as "Virgin oil," is made from hand-picked fruit. The fruit is crushed so as not to break the seed. The pulp is treated with water and again pressed, yielding a product which is employed as salad oil. The

pressed pulp is again treated with hot water, and subjected to high hydraulic pressure; this process gives an oil known as "olive oil foots." It is employed in the manufacture of soaps, particularly castile soap, and as a lubricant. An oil is also extracted from the seeds. It is much like that from the pulp.

CHAPTER XXXVII

CONVOLVULACEÆ (Morning Glory Family)

The representatives of this family are found chiefly in warm climates. There are close to 900 species in 400 genera. A number are of economic importance, among which may be mentioned the sweet potato, man-of-the-earth (*Ipomœa pandurata*), used as food by the Indians, moon-flower (*Ipomœa bona-nox*), morning glory (*Ipomœa purpurea*), cypress vine (*Quamoclit quamoclit*) and the bindweeds (*Convolvulus* spp.).

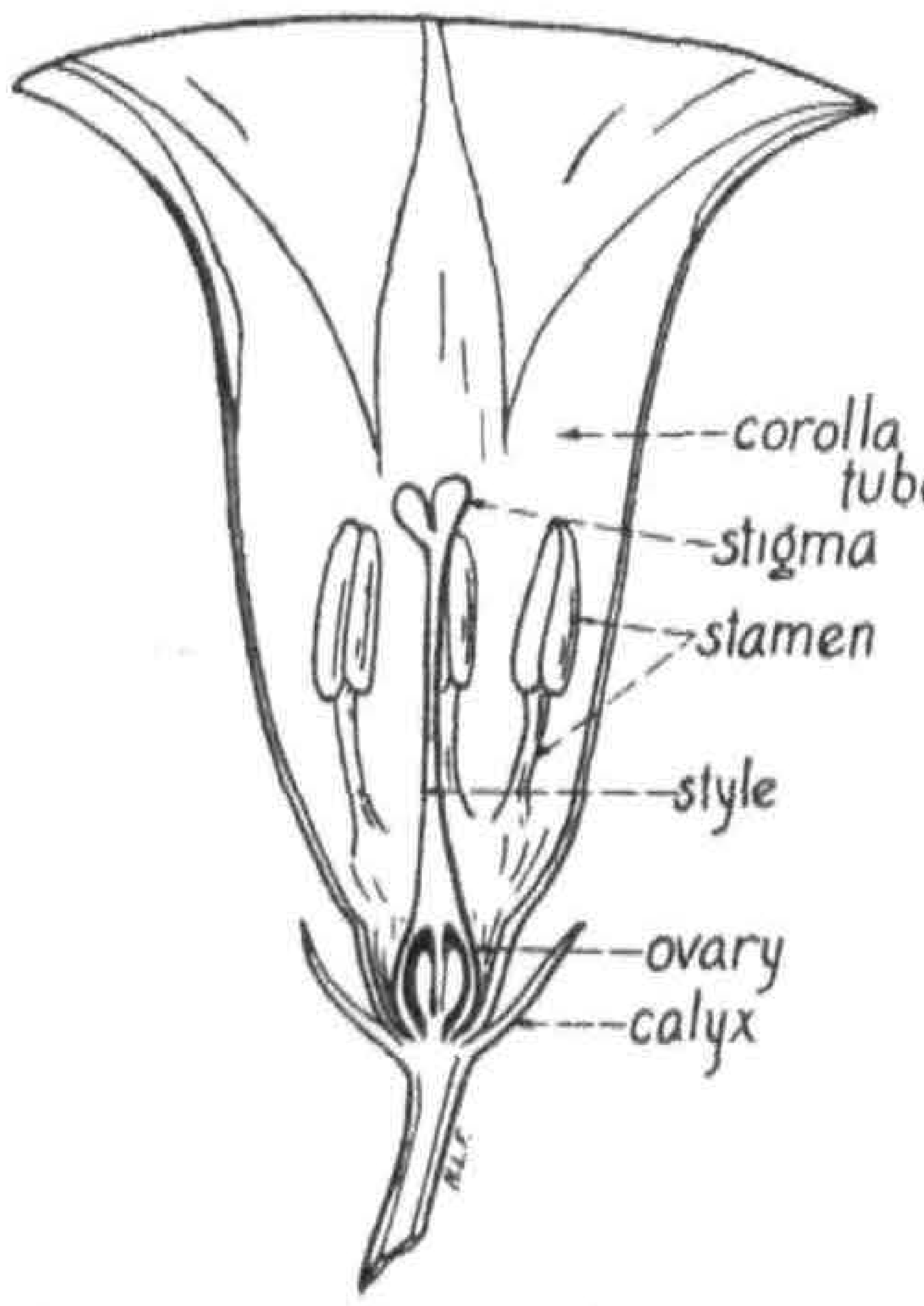


FIG. 228.—Flower of sweet potato (Ipomœa batatas), lengthwise section. (*After Sargent.*)

Most of the representative of this family are twining or trailing herbs; some tropical species are shrubs or trees, often with a milky juice.

Leaves.—The *leaves* are alternate, exstipulate, entire, dentate, lobed, or dissected.

Inflorescence and Flowers.—The *flowers* are in an axillary cyme, or sometimes solitary. They are regular, perfect and sympetalous (Fig. 228). The calyx is attached below the ovary, five-parted or five-divided, usually persistent, and imbricated in the bud. The corolla is plaited, convolute, or twisted in the bud, and becomes funnel-form, salver-form, campanulate, or tubular, with a five-angled, or five-lobed, or

entire limb (Fig. 228). The five *stamens* are inserted on the tube of the corolla and alternate with its lobes; all are anther-bearing. The filaments are filiform, or dilated at the base, and equal or unequal. The anthers are two-celled, and longitudinally dehiscent. The *ovary* is superior and usually has two cells (rarely three cells), each of which bears two ovules. In some instances, the ovary is falsely divided into four to six cells with a single ovule.

Fruit.—The *fruit* is a capsule; its seeds are endospermous.

KEY TO IMPORTANT GENERA

Stigmas capitate (knob-like).
  Stamens and style exserted, *Quamoclit.*
  Stamens and style included, *Ipomœa.*
Stigmas two, filiform or oblong, *Convolvulus.*

IPOMŒA BATATAS (Sweet Potato)

Roots and Stems.—The sweet potato is a sinistrorse-twining, trailing, perennial herb with very much thickened roots. The "sweet potato" itself is often designated as a "root tuber." The fleshy roots have stored within them large quantities of starch. They should not be confused with the tubers of the Irish potato. Sweet potato "tubers" are roots, while Irish potato "tubers" are stems.

Propagation.—In the propagation of sweet potatoes, the usual practice is to place whole small roots in the hotbed. Sprouts arise from within 3 to 4 weeks from advetitious buds —meristematic tissue located mostly at the base of fibrous lateral roots. Sweet potatoes are also sometimes propagated by root cuttings planted directly in the field, and in the South, the late crop is grown from vine cuttings taken from the early crop.

Leaves.—These are alternate, heart-shaped, petiolate, dark green, and glossy.

Inflorescence and Flowers.—The large, purple, conspicuous flowers are axillary, solitary or cymose. The sympetalous corolla is 1 to 2 inches wide, funnel-form, and has a five-lobed limb, and plaited tube. The corolla is folded longitudinally and twisted usually to the right in the bud. The stamens are as given under the family description. The two- to four-celled ovary has a thread-like style which bears one or two stigmas. The fruit is a capsule.

In northern latitudes, the sweet potato rarely blossoms, and never matures seeds.

Geographical, and Environmental Relations.—The original home of the sweet potato is the West Indies and Central America. Since the sweet potato is of tropical origin it is largely grown in the Southern States, the five leading ones being North Carolina, Georgia, Alabama, Louisiana and Mississippi. Ample sunshine and high temperatures favor its growth. Although a heavy rainfall is desirable during the first part of the growing season, the maturing of the roots proceeds best with rather dry weather. They do best in well-drained, light soils.

Closely Related Species.—The southern, juicy varieties of sweet potatoes are called "yams." They should not be confused, however, with the true yams, or Chinese potatoes of commerce, which belong to the species *Dioscorea batatas*, in a family (Dioscoreaceæ), closely related to lilies. This is a tall climbing plant with simple cordate, shining leaves, small, white flowers, and large tubers.

Types and Varieties.—Sweet potatoes may be divided into two groups upon the basis of the amount of water and sugar present: (1) *Dry sweet potatoes* are ones in which the flesh is dry, mealy, and yellow; they are the sorts most desired in the Northern States. The Jersey type, which includes spindle-shaped varieties, is probably the best known. (2) "*Yams*" are sweet potatoes in which the flesh is watery, rich in sugar, soft and gelatinous when cooked. They are the

sorts most in demand in the South. Common southern sorts ("yams") are Triumph, Nancy Hall, Dooley Yam, Vineless Yam, Sugar, Southern Queen, Florida.

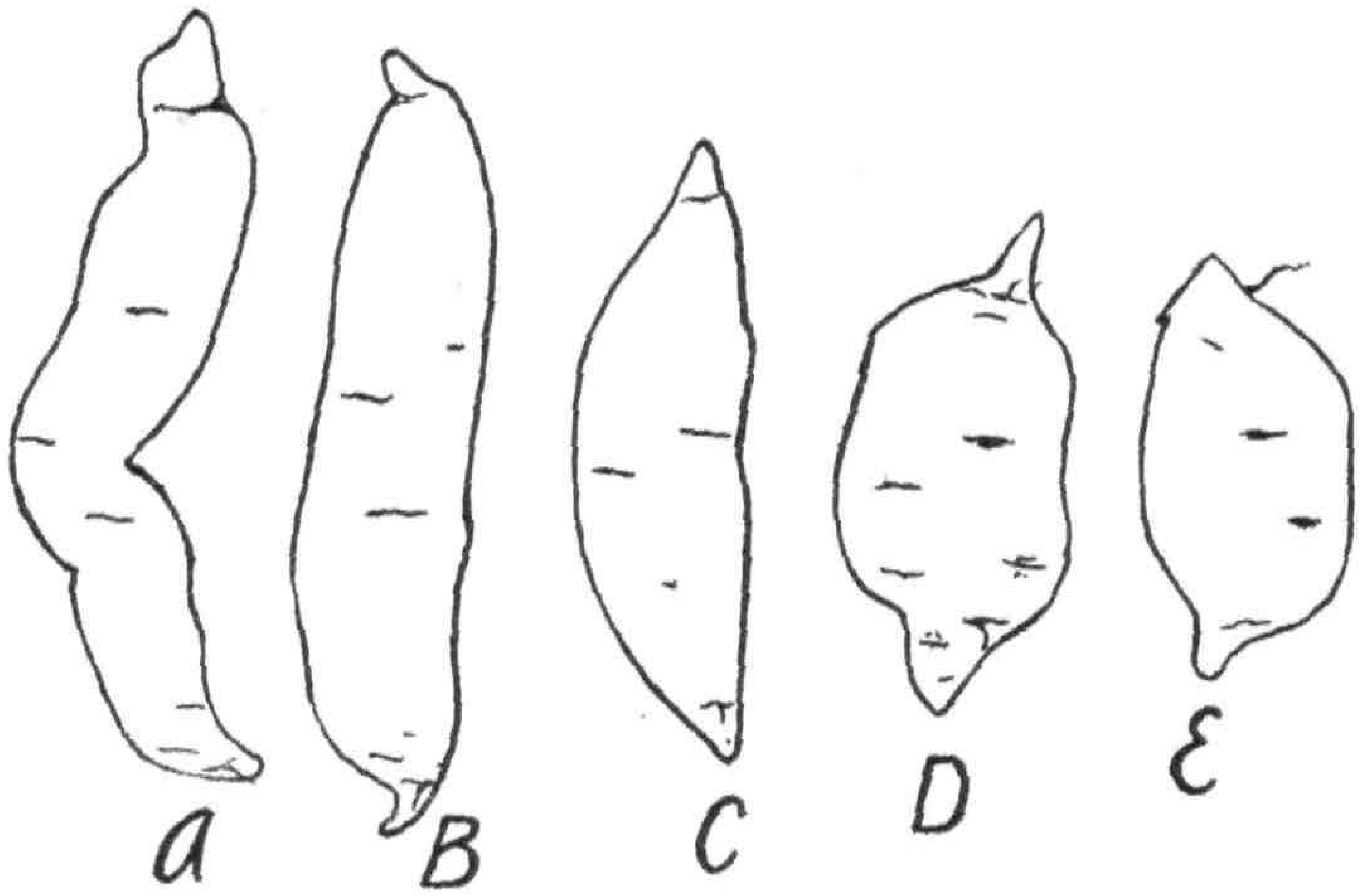


FIG. 229.—Types of sweet potatoes (Ipomœa batatas). *A*, Black Spanish; *B*, Shanghai; *C*, Big Stem Jersey; *D*, Red Bermuda; *E*, Southern Queen. (*Modified after Corbett.*)

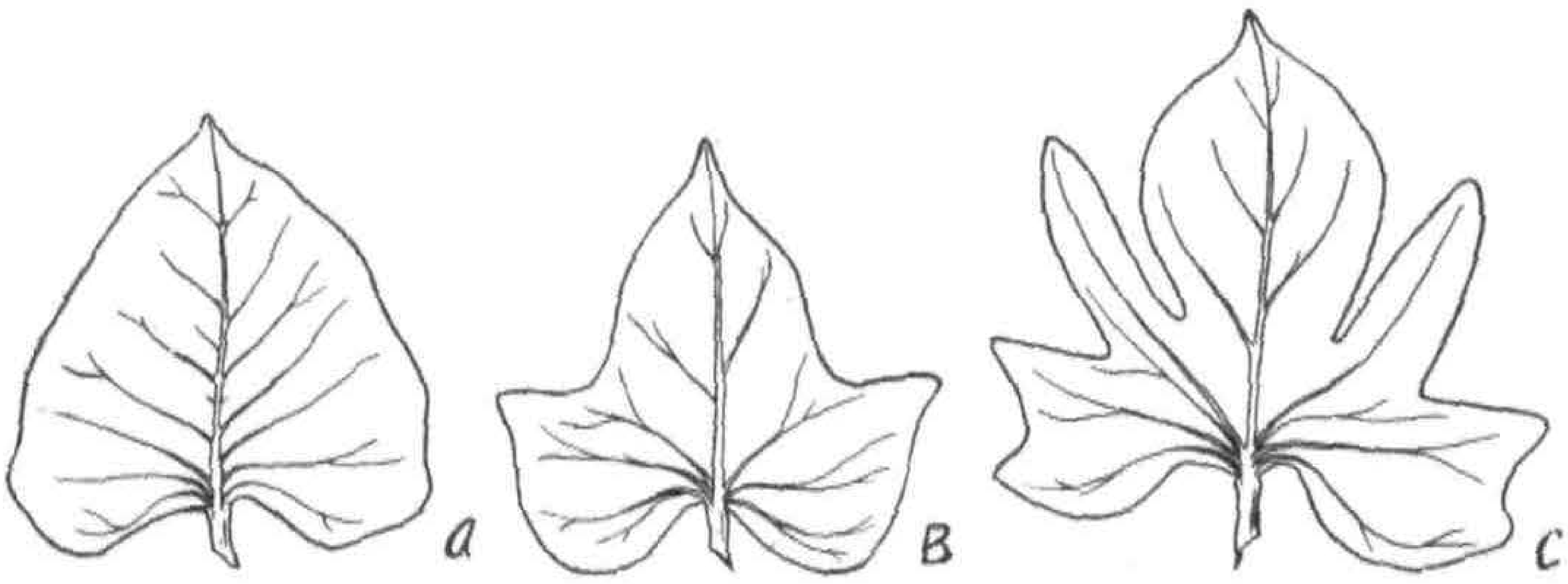


FIG. 230.—Types of sweet potatoes based upon the character of the foliage. *A*, entire or round; *B*, shouldered; *C*, deeply cut or lobed. (*After Price, Texas Agr. Exp. Sta.*)

KEY TO GROUPS OF SWEET POTATOES

Leaves deeply lobed or parted.
   Purple stain at base of leaf-blade—*Ticotea group*. Ticotea and Kaoli.
   Leaves without purple stain at base—*Belmont group*.

Belmont section—vines long and creeping. Belmont, Georgia, Eclipse Sugar Yam. Bunch section—Vines very short and bushy.
Gros Grandia, Vineless, Bunch Candy Yam.
Leaves not deeply lobed or parted.
Purple stain at base of leaf.
Stems purple or greenish with decided purple tinge—*Spanish group.*
Yellow Spanish section—Roots light to russet yellow, Pierson, Yellow Spanish, Triumph.
Bermuda section—Roots yellow, splashed with pink to purple, Red Bermuda, Porto Rico, Creola.
Spanish section—Tubers smoother and more regular in this group—Red Spanish, Dahomey.
Stems green.
Leaves entire to slightly shouldered—Roots white—*Shanghai.*
Leaves toothed with 6 to 10 marginal teeth. Roots salmon—*Florida group*—Florida, Nancy Hall.
Leaves without purple stain at base.
Stems purple—*Southern Queen group*—White Yam, Southern Queen.
Stems green.
Stems medium to large-roots yellow tinged with salmon—*Pumpkin group*—Pumpkin Yam, Norton.
Stems slender—roots russet yellow or red. *Jersey group.*
Red Jersey section—roots red—Red Jersey, Japan Brown.
Yellow Jersey section—roots yellow—Vineland Bunch, Big-Stem Jersey—Yellow Jersey, Gold Skin.

(*Adapted from Thompson and Beattie.*)

Uses.—Sweet potatoes are used chiefly as a human food. Some of the coarser varieties are grown for hog pasture. The vines have some value as a stock food. Flour, starch, glucose, and alcohol are minor products of the root. Small-sized sweet potatoes, known as "seconds," are canned. Kiln-dried sweet potatoes produce a product very similar to corn meal in its chemical composition.

References

GROTH, B. H. A.: The Sweet Potato. Contrib. Bot. Lab. Univ. of Pa., 4: 1–104, 1911.

THOMPSON, H. C., and BEATTIE, J. H.: Group Classification and Varietal Descriptions of American Varieties of Sweet Potatoes. U. S. Dept. Agr. Bul. 1021: 1–30, 1922.

CHAPTER XXXVIII

SOLANACEÆ (Potato Family)

The potato family is a large one, chiefly tropical; it has about 1,600 species in 70 genera. A number of these are important medicinal and food plants. Here are included such economic forms as Red or Cayenne pepper, tobacco, common Irish potato, eggplant, tomatoes, belladonna (*Atropa belladonna*) which furnishes the atropin of commerce, thorn apple (*Datura*), petunia, etc.

Representatives of the family are either herbs (potato, tobacco, tomato), shrubs (*Lycium* spp.), vines (*Solanum dulcamara*, bittersweet), or trees in some tropical species of *Datura*.

Leaves.—These are alternate, rarely opposite, without stipules, and entire, toothed, lobed or dissected.

Inflorescence and Flowers.—The inflorescence is mostly cymose, sometimes imperfectly racemose, umbellate, or paniculate. The flowers (Fig. 232) are regular, or nearly so, perfect, and vary in color. The *calyx* is inferior, and usually with five united lobes. The *corolla* is sympetalous, mostly five-lobed. The corolla varies considerably in shape: rotate (tomato), bell-shaped (*Physalis*), funnel-form (*Lycium vulgare*), salver-form or tubular (*Petunia* spp.) There are as many *stamens* as corolla lobes, alternate with them, and inserted on the tube; in most genera, the stamens are all equal and bear perfect anthers, but in *Petunia*, for example, there are four perfect stamens, the fifth being very much reduced or entirely absent; the anthers are two-celled, dehiscent at the apex or along the sides. The single *ovary* is

usually two-celled (rarely three- to five-celled, as in *Lycopersicon* spp.), the numerous ovules being on axile placentas; the style is slender, simple, and the stigma terminal.

Fruit.—The *fruit* is either a berry (potato, tomato), or a capsule (tobacco, petunia). In both cases, it bears numerous seeds, which have a fleshy endosperm.

KEY TO IMPORTANT GENERA

Fruit a berry (Fig. 233).
  Anthers opening by a terminal pore or slit (Fig. 232), *Solanum* (potato and eggplant).
  Anthers opening longitudinally.
    Flowers white, *Capsicum* (pepper).
    Flowers yellow, *Lycopersicon* (tomato).
Fruit a capsule (Fig. 244).
  Capsule generally prickly, *Datura* (thorn apple, Jimson-weed).
  Capsule not prickly.
    Flowers paniculate or racemose; stamens nearly uniform in length, *Nicotiana* (tobacco).
    Flowers solitary; stamens very unequal, *Petunia* (petunia).

SOLANUM

The *Solanums* are either erect herbs (as *S. nigrum*, the black nightshade, and the common potato, etc.), or climbing herbs (*S. dulcamara*, bittersweet). In most species, the stems and leaves bear a stellate (star-shaped) pubescence.

Leaves.—The *leaves* are alternate, exstipulate, and lobed or pinnately dissected.

Inflorescence, and Flowers.—The *inflorescence* is cymose (bittersweet), umbellate (black nightshade), recemose (*S. carolinense*, horse nettle), or rarely paniculate. The *flowers* (Fig. 232) are perfect and regular; in color, they are white (*S. tuberosum* varieties and *S. nigrum*), blue (*S. elæagnifolium*, silver-leaved nightshade, and *S. tuberosum* varieties), yellow (*S. rostratum*, sand bur), or purple (*S. dulcamara*). The *calyx* is bell-shaped or rotate, generally five-parted or

five-cleft. The *corolla* is rotate or rarely broadly bell-shaped, the tube very short, the limb plaited, five-angled or five-lobed. There are five *stamens* inserted on the throat of the corolla (Fig. 232); the filaments are short, the anthers converge around the style, and are usually dehiscent by a terminal pore, sometimes by a short introrse terminal slit, and sometimes longitudinally. The *ovary* is superior, usually two-celled; its style is slender and simple, and the stigma terminal.

Fruit.—The *fruit* is a many-seeded berry; the calyx is persistent at the base, and in some species (*S. rostratum*) encloses the berry.

Geographical.—There are about 900 species of *Solanum*, widely distributed, but most abundant in tropical America.

Key to Important Species of Solanum

Not tuber-bearing.
- Plant not prickly or spiny.
  - Erect herbs or shrubs.
    - Fruit ovoid or egg-shaped, yellow with purple or violet streaks or splashes, often 4 to 6 inches long, *S. muricatum* (pepino, melon pear).
    - Fruit a small, spherical berry, not over 1 inch in diameter.
      - Peduncles one- to three-flowered; ripe berries green, *S. triflorum* (wild tomato, cut-leaved nightshade).
      - Peduncles bearing small cymes, three- to ten-flowered; ripe berries black, *S. nigrum* (black or common nightshade).
  - Climbing vines, *S. dulcamara* (blue bindweed, bittersweet).
- Plant prickly or spiny.
  - Berry not enclosed by the calyx.
    - Flowers light blue or white; fruit a small spherical berry, *S. carolinense* (horse-nettle).
    - Flowers purplish; fruit large, *S. melongena* (egg plant).
  - Berry enclosed by calyx, *S. rostratum* (sand bur, buffalo bur).

Tuber-bearing.*
- Corolla rotate.

* Berthault in his monograph on the tuber-bearing *Solanums*, has a key to 37 species. A portion of this key is here included (modified) to show the relation of common potato to some wild tuber-bearing species.

Points of sepals long and tapering.
Leaves oval, *S. tuberosum* (common potato).
Leaves elongated, *S. immite*.
Points of sepals long, not tapering much; leaves oval, *S. chiloense*.
Points of sepals short.
Anthers straight, smooth, somewhat elongated, *S. utile*.
Anthers swollen, roughened, *S. maglia*.
Corolla star-shaped, *S. jamesii*, *S. commersonii*, etc.

SOLANUM TUBEROSUM (Potato)

This species includes all the varieties that are of value for food. They are usually called Irish or common potato, but also white, English, and round potato.

The potato is a branched, more or less spreading herb, growing to a height of 2 to 5 feet or more. It has annual aerial stems, but is practically perennial by means of its tubers or underground stems.

Roots.—Upon the whole, the development of the root system is less pronounced than in most other crops. The roots are fibrous and fine. They penetrate the soil to a depth of 3 to 4 feet and frequently extend horizontally 2 feet or more from the plant.

Stems.—Potato stems are of two general kinds as to medium in which they grow: *Underground* and *aerial*. The underground stems (Fig. 12) are slender rhizomes, or are swollen to form tubers ("potatoes"). The aerial stems are the ordinary foliage-bearing stems. The discussion of rhizomes and tubers is given on pages 31 to 33.

Stem (aerial).—The aerial or foliage stem of the potato is herbaceous and generally erect when young, but usually becomes spreading later. It is smooth and generally solid. It has no ribs at first, but as it develops, it becomes more or less quadrangular.

Leaves.—Potato leaves are compound pinnate, with more or less petioled leaflets. The petiole bears a number of

supplementary leaflets which vary in number and importance with the age of the plant. The rachis is decurrent (Fig. 12) on the stem. The leaflets are oval, acuminate, and the base heart-shape or oblique in shape. The leaves as well as the

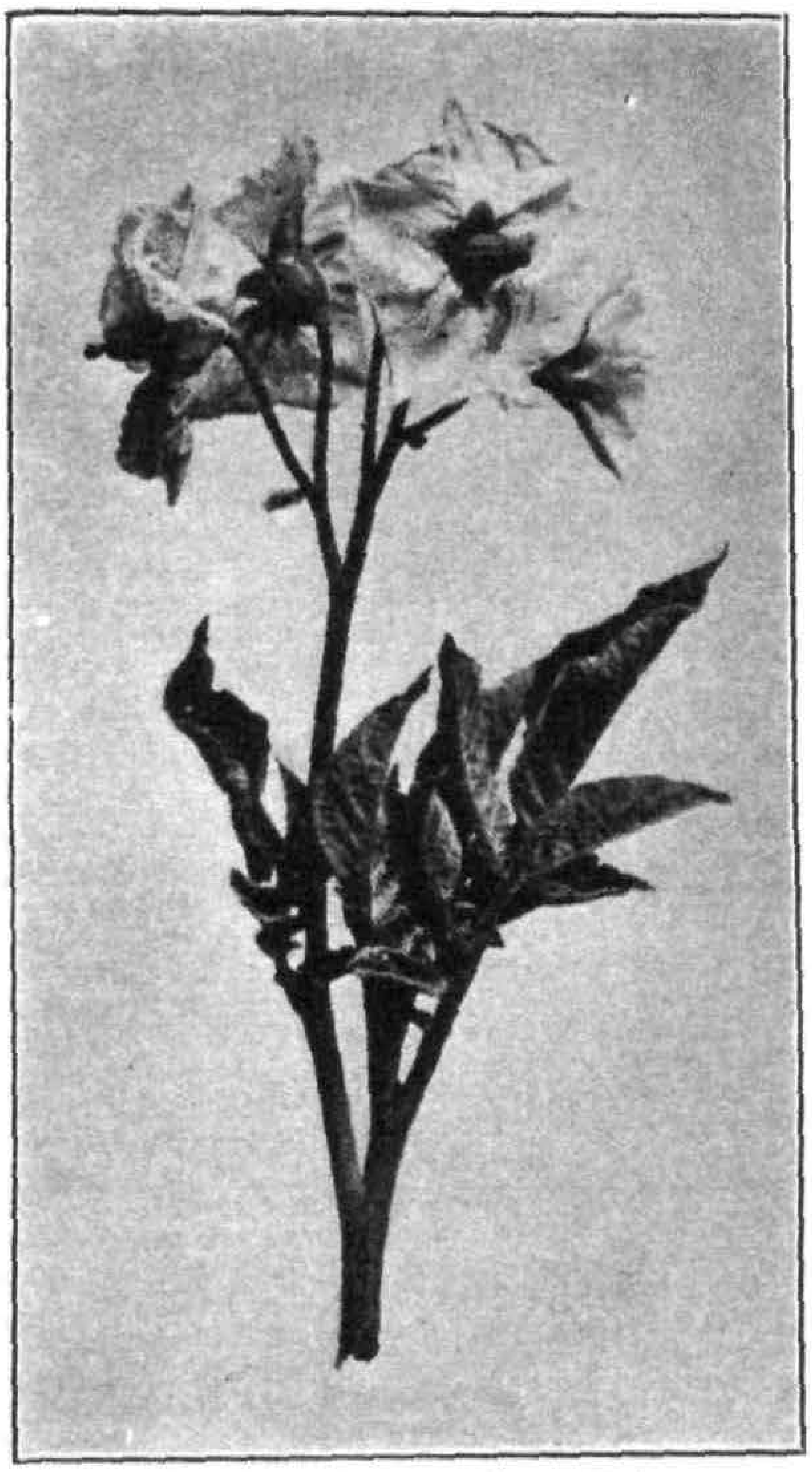


FIG. 231.—Flowering branch of potato (Solanum tuberosum).

stems are characterized by a narcotic smell. At the beginning of their development, the leaves are often simple, but they increase in complexity with age. The single terminal leaflet, which frequently appears alone, is soon followed by two lateral leaflets, and these by others, so that the leaf soon becomes distinctly pinnatifid.

Considerable differences have been found to exist in the appearance of the leaves of the different agricultural varieties.

Flower (Fig. 232).—The corolla is tubular, with five lobes. It is white, yellow, purple, or blue in color and 1 to 1½ inches in diameter. There is a single whorl of five stamens (occasionally four or six) which alternate with the corolla lobes, and are attached to the tube. The stamens are straight, and bear erect anthers which are longer than the filaments and open only at the top. Anther color varies from a pale

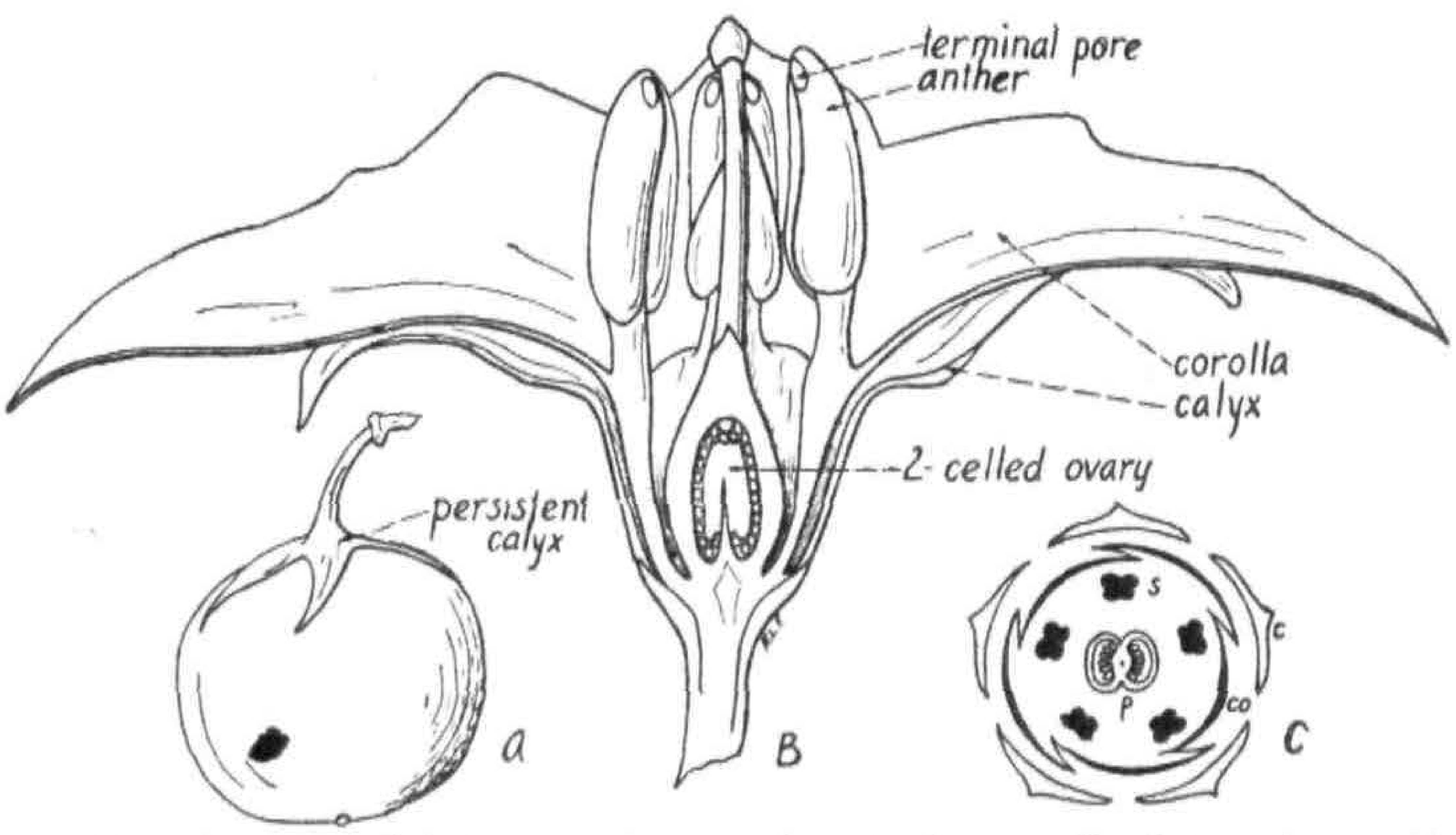


FIG. 232.—Potato (Solanum tuberosum). *A*, berry; *B*, flower in median lengthwise section; *C*, floral diagram.

lemon-yellow to a bright orange-yellow. As a rule, those varieties with pale, lemon-colored anthers do not produce viable pollen.

Two kinds of pollen grains have been observed. Those of most varieties are variable in size, irregular in shape, roughened, and largely impotent. Those of the other type are smooth, spherical, and potent. The latter kind are found only on varieties which bear fruit. Some varieties produce both kinds of pollen grains, but such plants do not always produce fertile flowers. Hence while the presence of round pollen grains seems to be necessary to the production of fruit,

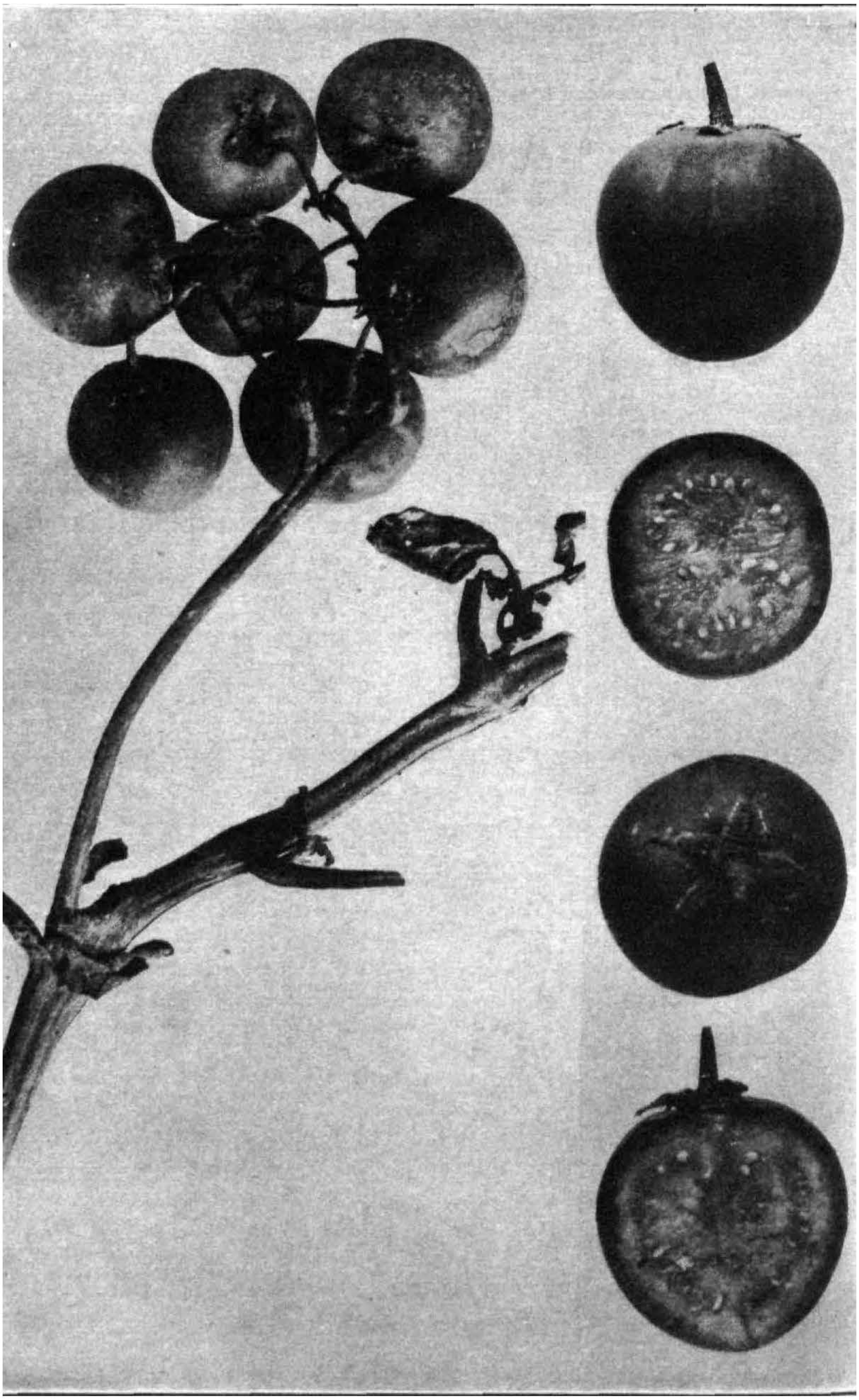
their presence by no means assures that the ovary will be formed or fruit produced. The ovary consists of two carpels with numerous ovules in each locule.

Opening of Flower and Pollination.—The anthers are mature at the same time that the stigmas are receptive. The flowers have been found to open between 5 and 6 o'clock a.m. The pollen is usually shed on the second day of blooming, and at this time, the pistil is most receptive. The anthers open at the top by a pore and, in some cases, split for a short distance. The pollen is carried by the wind. The flowers produce no nectar and are not visited by insects to any extent, although several species of insects have been reported as visiting the flowers. Observations indicate that self-fertilization is natural to the species. The flowers wither about the fourth day, in the profuse-seeding varieties.

It is commonly thought that potatoes do not fruit as freely now as formerly, due to the fact that large production of tubers has caused a degeneracy in seeding power. While many of the varieties seldom bloom, and more rarely set seed, some of the best varieties bloom freely and under proper conditions set seed. Fraser says, as a result of working with 300 varieties, many of which were grown for several years, that it is seldom that a variety will not bloom at some time in its life; furthermore, he found that many of the heaviest yielding varieties bloomed as freely as those of less value.

In many varieties, the flowers do not open.

Fruit and Seed.—The fruit (Fig. 233) is a globular or short oval berry with two locules containing numerous small, kidney-shaped seeds attached to the thick axil placenta and embedded in a green acrid pulp. The fruit is called by various names, such as "potato ball," "potato apple," or "apple" but is commonly referred to as the "seed ball." In color the seed balls are brown, purplish green, or green tinged with violet. Single fruits may contain from a few to as high as



200 or 300 seeds, but sometimes no seeds are produced. Fitch found no seeds in 650 seeds balls of Early Rose. One seed ball from a Pearl crossed with a Rural contained no seed, while six seed balls of the reciprocal cross all bore abundant seeds.

Germination of Seed.—Potatoes are seldom propagated by seed except for the production of new varieties.

Germination of seed begins in about five to seven days after planting, being complete in about eleven to sixteen days. The primary root appears first, soon becomes curved, and is followed by the axis of the hypocotyl. The cotyledon leaves are smooth, oval, and more or less elongated, while the first foliage leaves are provided with unbranched hairs.

Development of the Seedling.—From the thirty-seventh to the fifty-sixth day after seeding, the stolons arise (Fig. 234); the first pair comes from the axils of the cotyledon leaves. These slender cylindrical stems possess small rudimentary leaves. They trail along on the ground and finally penetrate the soil. When their tips strike the ground, they begin to swell and form tubers. Hence the first tubers of the plant, grown from seed, are developed at the tips of slender stolons coming from the axils of the cotyledon leaves. Roots soon arise from the stolons. Secondary stolons appear in the axils of the first foliage leaves.

Tubers from Seedlings.—Tubers produced on seedlings are usually small the first year. However there has been reported a tuber weighing over 7 ounces that was formed the first year. The Burbank potato was full-sized the first year from seed. It is reported from Svalof (Sweden) that tubers usually attain normal size and type after about the third year from seed.

FIG. 233.—Potato seed balls, showing a cluster, and lateral, sectional and basal views. (*After Stuart, U. S. Dept. of Agri.*)

Tuberization.—It has been noted previously that tubers, developed on a plant grown from seed, come at the tips of stolons arising on the stem above ground. However, when the tuber as a cutting is used in propagation, the young tubers form at the ends of long, thin rhizomes (underground stems) which arise underneath the ground from axillary buds on the main axis or stem (Fig. 12). The length of the stolon seems to be constant and a strong variety characteristic. In cultivated varieties, it should not exceed 3 or 4 inches. In *S. commersonii*, it is reported as sometimes reaching a length of 10 feet. The tubers or swollen stems bear a number of buds, and these buds send out sprouts when the tuber is planted. The tuber-bearing stolons usually begin to develop within a week or ten days after the plants have appeared above the ground, those of early varieties appearing before those of later varieties. Tuber formation begins at about the end of the period of flower-bud development.

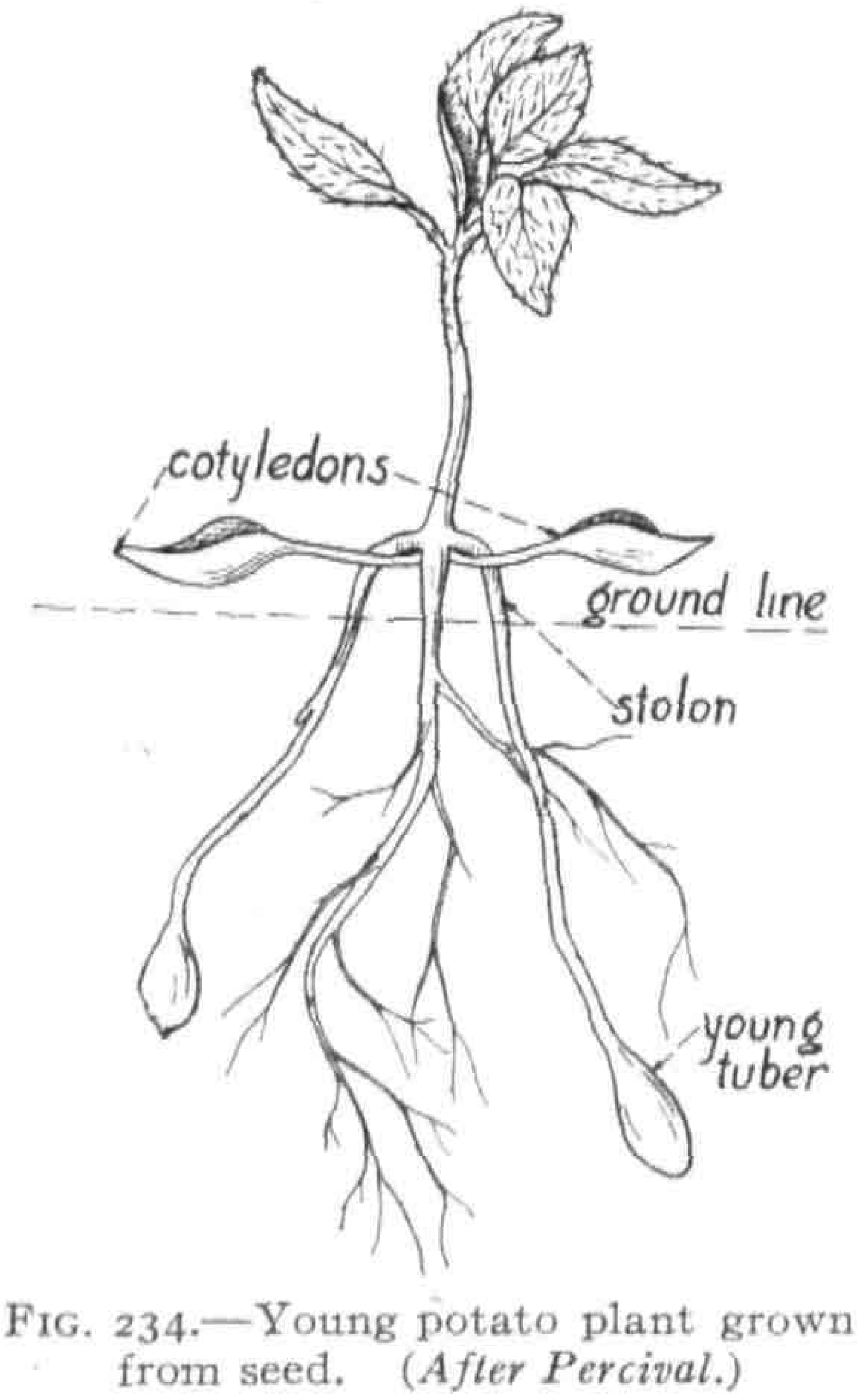


FIG. 234.—Young potato plant grown from seed. (*After Percival.*)

As a rule, the tubers are formed beneath the ground as noted above; but under abnormal circumstances, or when disturbed by diseases, the above-ground stems may produce tubers. For example, when the fungus, *Rhizoctonia*, which shuts off the downward movement of elaborated foods from the leaves to the underground tuber-forming stems, is active, normal tuberization under ground is interfered with and the

stems above ground will have a tendency to swell and produce small tubers. This phenomenon is often indicative of *Rhizoctonia*.

The causes of tuberization are not well understood. In general, it is found that darkness and low temperature favor the development of potato tubers. Tuberization is also facilitated somewhat by checking the growth of shoots or fruits. There is evidence that tuberization is favored by short days.

There is some basis for the theory that the formation of the tubers is associated with the presence of certain fungi. It is certain that tuber production is encouraged in certain orchids when the stem or root is infected with the proper fungus. The fungus appears to check the growth of the terminal bud and cause the development of hypertrophied cells.

When the potato was first introduced in France, it was found that when tubers were planted a crop was produced, but when seed was sown no tubers were obtained. From this it was inferred that when tubers were planted they infected the new ones, while the seed, free of fungi, did not furnish a supply to infect the stolons, and hence tubers could not form. However, no difficulty is now experienced in securing tubers from seed because the soil has become inoculated with the proper fungi. If this theory is correct, the potato tuber is in reality a gall, produced by a foreign organism.

In the potato, tuberization has been induced in concentrated solutions of sucrose or glycerin, etc., independent of fungi. Similar results have occurred in the case of orchids, onions, and radishes. From this it seems that the formation of tubers may result when the osmotic pressure in the cultural medium is high. However, this alone does not appear to be the only determiner, since different results follow the

use of glucose and glycerine solutions of equal pressure. It certainly seems that plenty of sugar must be present for starch formation, and perhaps also for tubers to form. From this fact, that a more concentrated cell sap is usually present in fungi than in other plants, it does not seem unreasonable to suppose that the rôle of fungi in tuberization consists in raising the concentration of the media which they enter. It has actually been found that cultures of *Fusarium* in macer-

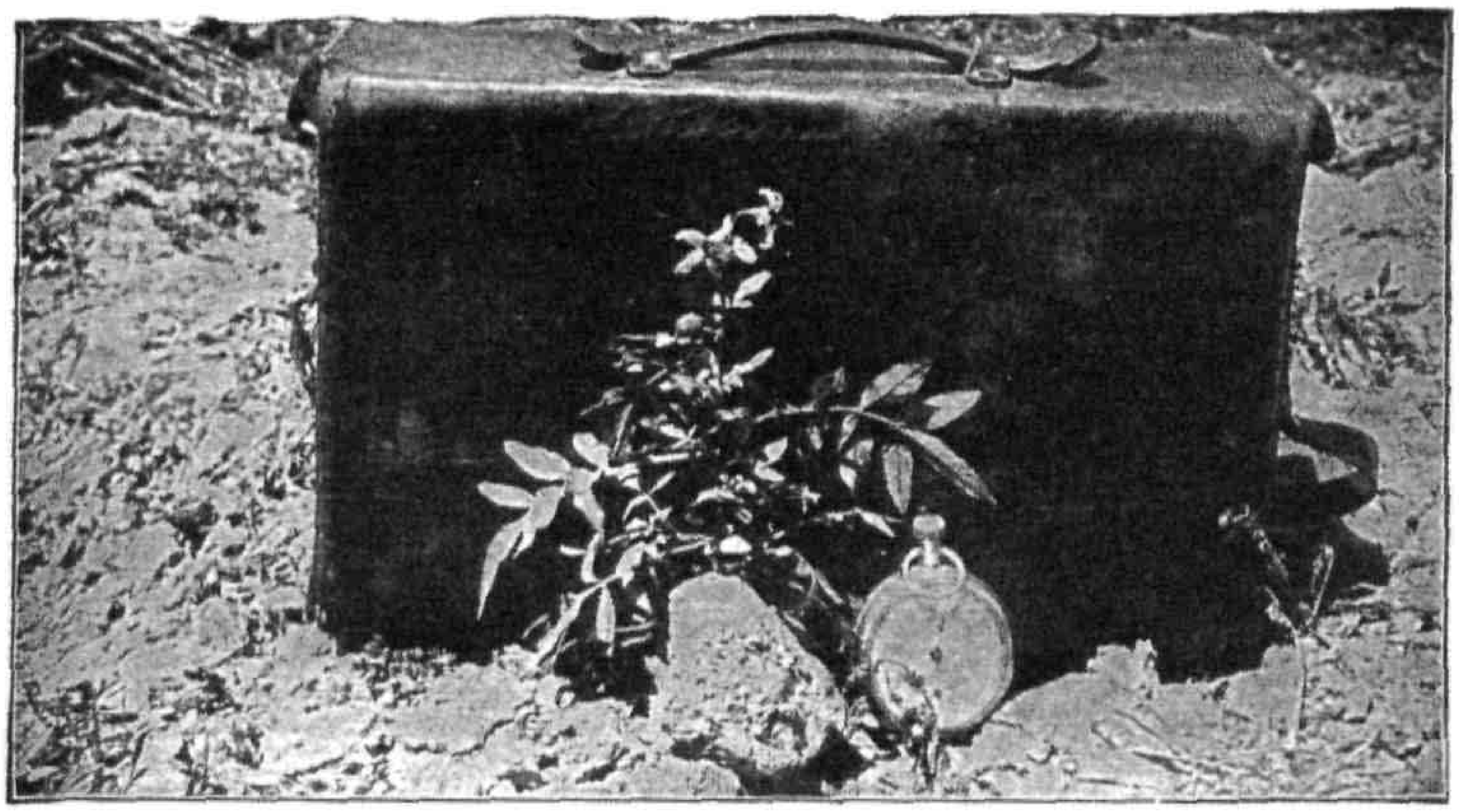


FIG. 235.—The wild potato of southwest United States (Solanum jamesii). (*After Fitch, Colo. Agr. Exp. Sta.*)

ated potato tuber preparations increase the concentration. In this connection, it is suggested that low temperatures and dryness of soil may induce tuberization through increasing the concentration of cell sap.

History.—It seems "that the potato was cultivated and utilized by the Chilean and Peruvian people before the arrival of the Spaniards. In 1533, Pizarro found the Chileans using the tubers of a plant as their principal food. There is no evidence that he or his party introduced them into Europe."

Wild plants have been found on the Peruvian coast, on the mountains of Chile, Central America, Mexico, and southwestern United States. However, without a doubt those which were introduced into Europe were from cultivated plants and not from wild tuberous American species. There is little doubt that South America, in the neighborhood of Quito, is the place from which the potato was first introduced into Spain early in the Sixteenth century.

After a careful study of all possible available types and species of *Solanum*, a perusal of the available literature

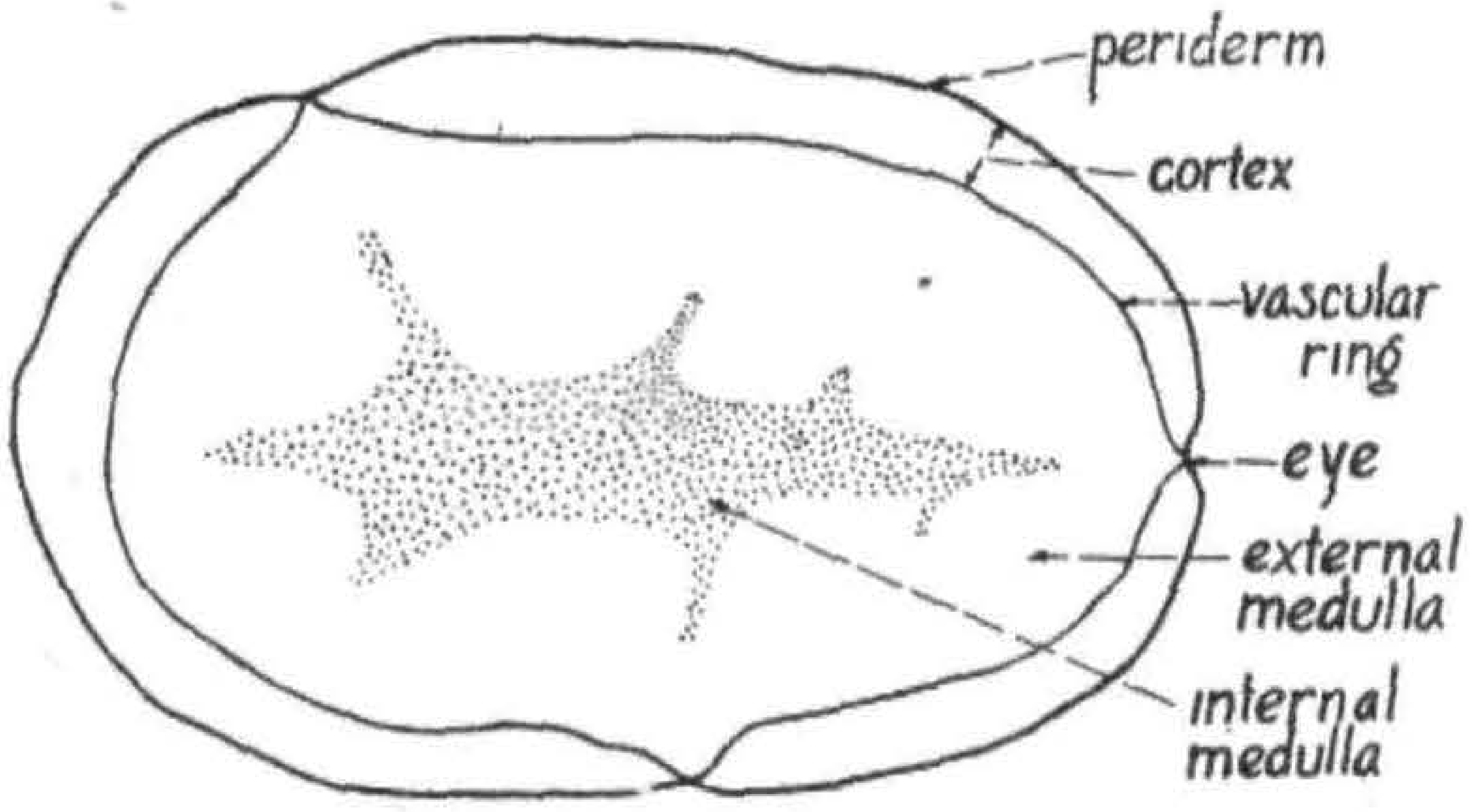


FIG. 236.—Diagrammatic section of potato tuber.

and records, F. Berthault has come to the conclusion that *S. tuberosum* is a distinct species which did not originate by mutation, or by slow changes, induced by cultural treatments, from wild species, and that it is characterized and differentiated from all other wild tuberous *Solanums* by its floral characters, notably its rotate corolla, and its calyx which is always mucronate (sharp-pointed). All agricultural varieties of the cultivated plant (potato) have been found to correspond to these characters.

Varieties.—There are at the present time over 500 named varieties of potatoes in the United States. Many of these variety names are found to belong to potatoes which are identical in all respects. Usually, new varieties are the seedlings of established varieties.

The latest attempt at a classification of American potatoes is that of Stuart. In his "proposed system of classification" he gives the following "groups:" Cobbler, Triumph, Early Michigan, Rose, Early Ohio, Hebron, Burbank, Green Mountain, Rural, Pearl, and Peachblow. Tuber, sprout and flower characters are made the bases of distinction of the groups. The student is referred to Bull. 176, U. S. Dept. Agr. (Professional Paper) for the descriptions of these groups.

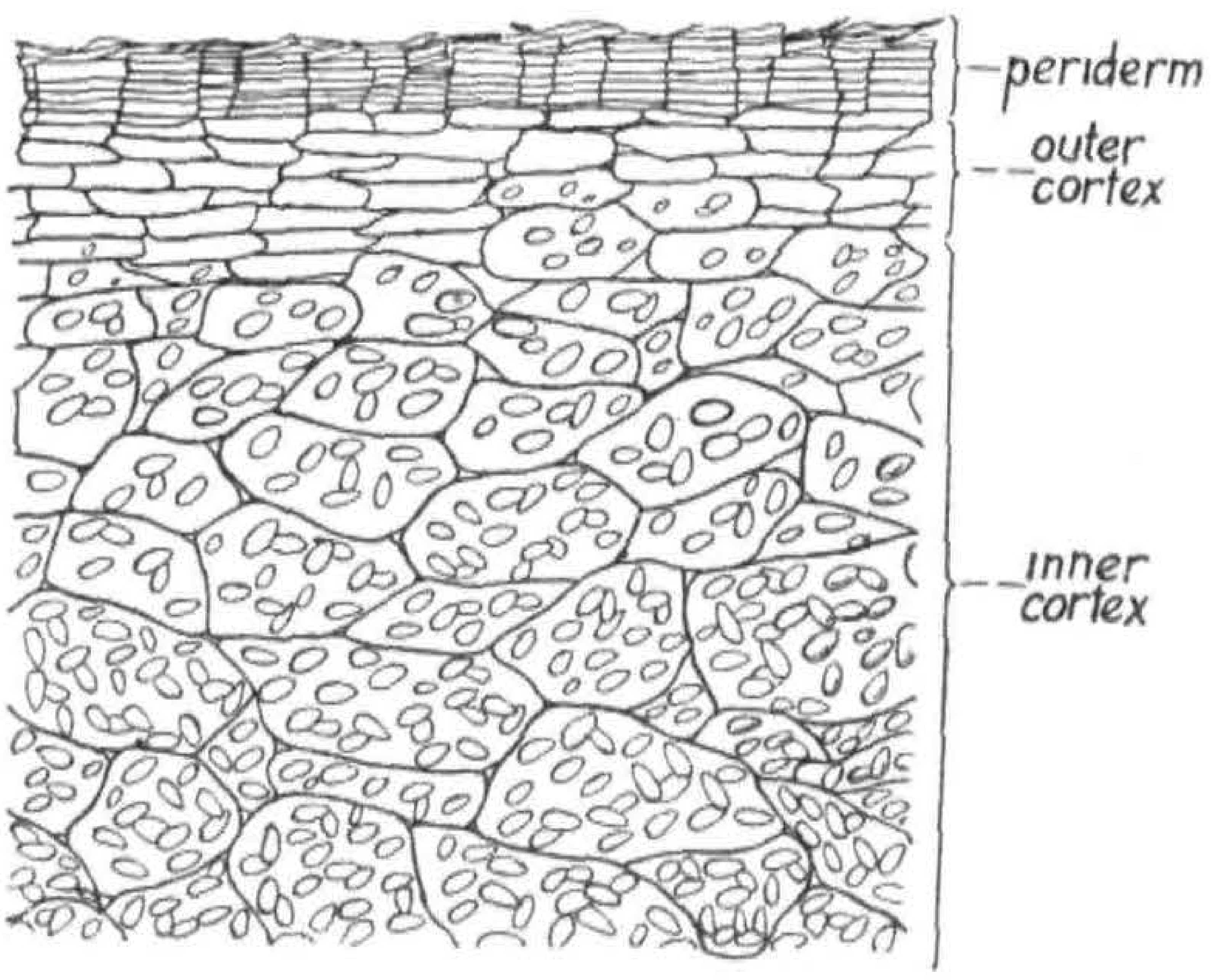


FIG. 237.—Microscopic section through the "skin" and portion of cortex of potato (Solanum tuberosum).

Tuber Morphology.—The potato tuber is made up of a number of zones or layers which are commonly grouped as follows (Figs. 236 and 237):

1. Periderm or skin.
2. Cortex.
3. Vascular ring.
4. External medulla.
5. Internal medulla.

According to Coudon and Boussard, these zones (excepting vascular ring) are proportioned (by volume) as follows:

	Per Cent.
Skin (average of two varieties)	8.79
Cortex (average of two varieties)	36.19
External medulla (average of five varieties)	34.17
Internal medulla (average of five varieties)	14.95

For consideration here, these zones are classified as follows:

1. Periderm or skin.
2. Vascular ring.
3. Parenchyma.
   (*a*) Cortex.
      1. External.
      2. Internal.
   (*b*) Medulla.
      1. External.
      2. Internal.

Periderm or Skin.—The stolon, which develops into the tuber, possesses the true stem structure. It has a thin epidermis, an outer parenchyma tissue or cortex, fibro-vascular bundles, and an internal parenchyma or medulla. As the tuber develops, the cortex becomes relatively reduced, the vascular bundles separate and the medulla becomes larger. The outer layers of cells of the cortex also undergo changes. The cells of these layers become corky and flattened, and so arranged that the vertical walls form straight lines and do not overlap. Their walls become suberized. The original true epidermis gradually dies and disappears entirely. These outer corky layers of cells constitute the periderm or skin of the potato. The outermost layers of periderm split off, giving some varieties a characteristic rough appearance. The cells of the different layers of periderm vary in size and shape in different varieties. The number of layers is usually 7 or 8, but it varies from 5 to as many as 13 and even 17. At the eyes, the periderm

(skin) becomes thicker. Lenticels are scattered over the tuber.

Some claim is made that thick-skinned varieties are of better quality than thin-skinned ones, but such is not always the case. A netted or rough skin develops on tubers of some varieties as they mature in storage, which suggests, that a rough or netted skin in these cases denotes maturity. Possibly this is sometimes the source of the common idea that a rough-skinned potato is of superior quality. The size and type of netting is found to vary with the variety and the conditions under which grown. Smoother skins are usually found on potatoes grown on sandy soils than on those grown on heavy soils. It has been found that the thicker and rougher-skinned varieties stand up better in shipping, and are preferable for this purpose even though they may have no greater merit in other ways.

Vascular Ring.—The vascular ring consists of a discontinuous circle of vascular bundles. It is located between the cortex and the medulla. At the eyes, the vascular tissue approaches the surface of the tuber. It maintains, however, its proper relationship with the other tissue, *i.e.*, between cortex and medulla. The cortical layer gradually becomes thinner as the vascular bundles approach the eyes. The vascular tissue is poor in starch. The vascular ring is easily recognized as a very narrow darkened ring near the edge of the exposed surface of a cut.

Parenchyma.—Almost the entire mass of tuber tissue inside of the periderm (skin), except the vascular tissue, is parenchyma, and will be referred to as such in this discussion.

The parenchyma is divided into two principal parts: the cortex, and the medulla.

Cortex.—The cortical layer of the parenchyma is just within the periderm. It is separated from the medulla by the vascular ring. The outer cortex is made up of smaller cells

than the inner cortex. The cells of the cortex are considerably smaller than those of the medulla, and hence the density of the cortex is greater. The cortex is darker in color than the medulla, which is probably due to its greater density. A thick and dense cortex indicates a potato of good quality. A thinner, more translucent cortex is said to indicate lower quality. The periderm, or skin, and the outer layers of cortex are removed when potatoes are peeled.

Medulla.—The medulla consists of all of the tuber inside of the vascular ring. It is divided into two parts, the external and the internal medulla. When a thin slice of potato is held up to the light, these two areas are easily distinguished; the external medulla appears darker and denser; the lighter color of the internal medulla is due to its greater percentage of water, and considerably less starch and other solid matter.

The internal medulla is usually more or less star-shaped. Many of the radiating areas of internal medulla penetrate deeply the outer medulla, some of them extending to the eyes. In some tubers, these two zones are more or less intermixed, with no definite zone boundaries. As a rule, in long potatoes, the central area is very much elongated and with lateral radiations, while in many round potatoes it is typically star-shaped. The greater the size of the internal medulla and the more its ramifications into the outer area, the poorer the quality of the tuber, since it means a larger area poor in starch and hence less mealy on cooking.

Shape.—The common tuber shapes are round, oblong, and elongated, in outline. One dominant form is found in each variety but never one exclusive form. New varieties based on tuber form are produced by a selection of tubers and are maintained only by continued selection.

In tuber propagation, there appear among the normal-shaped tubers a number of aberrant (diverging) forms which are usually in the minority.

Color.—The common tuber colors are yellow, red, violet of different shades, and variegated. Bluish forms are also known. Color variations has been found in a number of cases. In propagation by cuttings, yellow and streaked tubers have appeared from colored ones (red and violet). Yellow tubers have given red and violet ones, a white tuber has given two red and two white tubers, and one with a bluish color has given a series white in color. The Pearl with a brownish-white or a well-russeted skin is from the Blue Victor which has a purple color often streaked with white. When the white streaks cover an eye, the tubers from the eye usually come true (white) in following generations. The People's variety, also from the Blue Victor, is a deeper brown color than the Pearl. At the present time, white-fleshed tubers are the only ones accepted in American markets. Yellow flesh is correlated with a strong flavor and a poor quality, at least according to American standards. A number of yellow-fleshed varieties from France are found to be gummy and hard after boiling. They are considered by the French to be of prime quality, however. In this country, these varieties are considered of good quality for the making of salads and for frying.

Eyes (Fig. 236).—The buds of the potato tuber usually occur in groups, each group lying in a more or less depressed area. Such a group of buds is called the "eye." The depression is the axil of a scaly leaf which was in evidence when the tuber was young, but later disappears. The "eye brow" ("eye yoke") is the line above the depression—the line which separates the leaf from the stem. In reality, the eye is a lateral branch with undeveloped internodes, the whole tuber being generally a much-branched stem and not a simple shoot. The central bud in the "eye" is commonly the largest and strongest.

Fitch has noted that the "eye-brow" differs noticeably in vigorous and in degenerate tubers. In the latter, it is stronger and has a tendency to be longer.

Careful study shows that the buds or "eyes" are arranged alternately and at the same time spirally on the tuber. Beginning at one end of a tuber and proceeding toward the other end, at the same time turning the tuber, usually enables one to follow clearly the spiral arrangement.

The so-called "seed end," "rose" end, or "crown" of the tuber is opposite the point of attachment to the stem. The "stem" end is at the "base" or heel of the tuber. The eyes are more numerous and more vigorous at the seed end. Ordinarily, the terminal bud (at the "seed end") is the strongest and under proper conditions will be the only one to develop. The sprout produced by the terminal eye is spoken of as the "master sprout." The eyes vary in different varieties from very deep to level with the surface; the latter condition results in smooth potatoes. Deep eyes tend to hold moisture; as a result, decay is invited and hastened when the potatoes are stored. Smooth varieties occasionally give rise to deep-eyed tubers, although, as a rule, eye depth is maintained by tuber propagation. It is likely that the deeper-eyed plants give rise also to smooth tubers and that in seed propagation the same results follow as in the case of form and color.

The number of eyes varies considerably within the same variety; in one case, Rural New Yorker, it ranges from 7 to 28; and in Early Ohio, from 7 to 22. The number of eyes affects the quality, since the poorer zone of the potato (internal medulla) extends a branch to each eye, thereby increasing the percentage of internal medulla at the expense of the two outermost valuable layers.

Germination or Sprouting of Tuber.—Potatoes undergo some changes in storage. Not only do they lose water and

decrease in weight but they increase in sugar. When sprouting commences, the potato becomes sweeter, due to the conversion of starch into sugar by the enzyme diastase. In the whole tuber, the most vigorous sprouts usually arise from the terminal bud, but if the buds are separated before growth starts, they develop into shoots of approximately equal vigor. The tip of the main sprout grows upward. The underground stems bear tubers at their ends. These will not tuber if brought to the light but will develop into ordinary green-leafed shoots.

Physical Composition of Potatoes.—In all varieties the cells of the cortex are much smaller than those of the medulla. In general, potato varieties are characterized by their cellular density and can be grouped accordingly. The groups are not, however, clear-cut. Cellular density is an important factor to consider in the breeding of potatoes for table use, or for the industries. For table use, only those tubers should be selected which have small cells (high density), and for starch factories only those with large cells (low density). Even with the same amount of starch in two varieties, it is found that the large-celled one is the more valuable to the starch industry, due to the fact that in the small-celled varieties a larger number of the cells remain intact and do not give up their starch in the starch-removing process, while with the large-celled varieties fewer starch cells escape being broken up. In France, it was found that rich, compact (heavy) soils produced tubers with a low cellular density, while the lighter soils produced tubers with small cells and high density.

Chemical Composition of Potatoes.—A number of analyses of potatoes have been made in this country and in Europe. Gilmore gives the results of a number of these in the following table:

Source	No. of analyses	No. of varieties	Protein	Starch	Quality
Cornell	43	4	1.899	17.356	Very good.
Maine	16	4	2.170	18.037	Very good.
U. S. all sources	136	......	2.200	18.400	
France:					
Coudon and Boussard	7	7	2.676	11.798	Very good.
Coudon and Boussard	8	8	2.411	13.218	Good.
Coudon and Boussard	7	7	2.365	14.118	Passable.
Coudon and Boussard	12	12	2.090	16.047	Poor.

Water and nitrogen increase from the outer to the inner zones, while the starch content decreases.

The following table showing composition of the potato is from East:

Variety	Zone	Dry matter, per cent.	Total N, fresh basis, per cent.	Total N, dry basis, per cent.
Rural New Yorker No. 2	Cortical	20.95	0.46	2.20
	Outer Med.	18.46	0.47	2.56
	Inner Med.	14.04	0.45	3.23
Carman No. 3	Cortical	22.20	0.49	2.23
	Outer Med.	19.41	0.51	2.63
	Inner Med.	14.92	0.52	3.49

This table shows that the dry matter decreases from the outside to the inside of the tuber. The nitrogen content shows an increase, on dry basis, from the outside to the center, although on a fresh basis there seems to be no regularity of percentage, probably due to variability in water content. The inner cells of the cortex contain a much larger amount of starch than those of the external medulla, which in turn contain considerably more than the cells of the inter-

nal medulla. The outer cells of the cortex which are removed with the skin (in peeling) are comparatively low in starch.

Starch and Sugar.—Potato starch grains are egg-shaped or nearly spherical with eccentric markings, and with the hilum near the small end. Some varieties of potatoes are abundantly supplied with large starch grains with infrequent small ones, while in other varieties the reverse is the case. No correlation has been found between the size of the starch grains and the size of the tuber or its total starch content. In general, the early varieties contain large starch grains while the late varieties contain a larger proportion of small grains. Starch-grain formation is very slow. At first, many small grains are found, most of which later increase in size. This increase in size begins much sooner in early varieties than in late varieties.

In addition to starch, potatoes contain noticeable amounts of sugar. The average quantity is not far from 0.35 per cent. This sugar is lost in starch-making, but is utilized in the manufacture of alcohol.

"Mealiness."—In estimating cooking quality of potatoes, mealiness is the most important consideration. Mealiness depends quite largely upon the amount of starch in the cells. When boiled in water, the starch grains expand and coalesce. If there is sufficient starch, as is usually the case in the cortex, this expansion ruptures the cell walls, freeing their contents and producing mealiness. A deficiency of starch, as is usually the case in the cells of the internal medulla, produces swelling insufficient to rupture the cell walls; hence, sogginess results.

As has been shown, the different zones of the potato vary considerably in starch content, the cortex being highest, and the internal medulla lowest. If the internal medulla is large and has branches extending into the external medulla,

the tuber is likely to be hard and soggy when boiled and to contain zones or parts which will not mash uniformly and readily. The external medulla is usually well stocked with starch. When this is the case, and when the starch is distributed uniformly, leaving no "water areas," a high degree of mealiness can be expected in the boiled tubers, a condition necessary for high table quality in America.

Quality of Potatoes.—The standards for table quality in potatoes vary somewhat in different countries. The more noticeable differences seem to be between France and the United States. East notes that most of the potatoes which he examined, imported from France, had a yellow flesh, a strong flavor, and were firm and soggy after boiling. In France, potatoes are commonly cooked by frying in deep fat. For this purpose, a potato yellowish in color which holds its form, and is, as a result, more or less soggy after boiling, is preferred. These characteristics are usually found in potatoes which are low in starch and high in protein. In the United States, on the other hand, where probably nine-tenths of the potatoes eaten are boiled, a white, floury, starchy potato which is mealy and dry when cooked is demanded for table use. In Germany, table potato standards are more like those in the United States. In general, it is considered that for table use in this country potatoes must contain about 17 per cent. or more of starch. As a result of experimentation with 15 American varieties, East says: "It is quite evident then that potatoes having as far as possible a homogeneous flesh and containing as large an amount as possible of cortical and outer medullary layers in proportion to inner medullary layer, should be of the finest quality."

Degree of Maturity and Quality.—Analyses in the United States have shown that the "greater part of the total nitrogen is developed early in the growth of the tuber, while the

starch is stored up later." It was also found that "the starch grains of immature tubers are small in size and few in number." Tubers increase in desirability with maturity.

Degeneracy of the Potato.—The "running out" of potatoes is a common observation. New varieties are put on the market, are very productive for a varying number of years, then they usually begin to "run out" or degenerate.

In Colorado, varieties in the mountain districts do not tend to run out, or only very slowly, the tendency apparently being easily overcome by seed selection, while in the Greeley district, on the plains, at an altitude of 4,600 feet, the sexual tendencies and consequent degeneracy seem to overcome other influences, such as selection. At Svalof (Sweden) the opinion is held that in a variety of potatoes "there is no period of old age." On the other hand, degeneracy is believed to be the result of "factors which hinder the normal development of the plants and tubers or invite disease." Recently it has become known that degeneration of potato varieties is due to such diseases as leaf-roll, curly-dwarf, mosaic and spindling-sprout. It has been found that the progeny of plants with normal foliage and high yield may very suddenly degenerate into dwarfish plants affected with the above-mentioned diseases. The leaf-roll, curly-dwarf and mosaic troubles are passed from generation to generation by means of the tubers. The observations are significant in that they show that seed selection may not always insure against "running out."

Environmental Relations.—The potato is a native of the high, cool regions of Mexico and South America. In the United States it thrives best in a cool, moist climate as is evidenced by the fact that the five leading potato States touch the Canadian border. It is well adapted to elevation up to 8,000 feet in the Central Rocky Mountains. Smith has shown that the potato makes its best development in those

sections of the country where the mean annual temperature is between 40° and 50°F., and where the mean for July is not over 70°F.

The plant is grown on both heavy and light soils, but the latter are preferred; upon these, the plant is less subject to disease, the tubers are of better quality and smoother, and come to maturity more quickly.

Uses of Potatoes.—Potatoes are put to the four following chief uses: (1) human food; (2) commercial starch; (3) stock

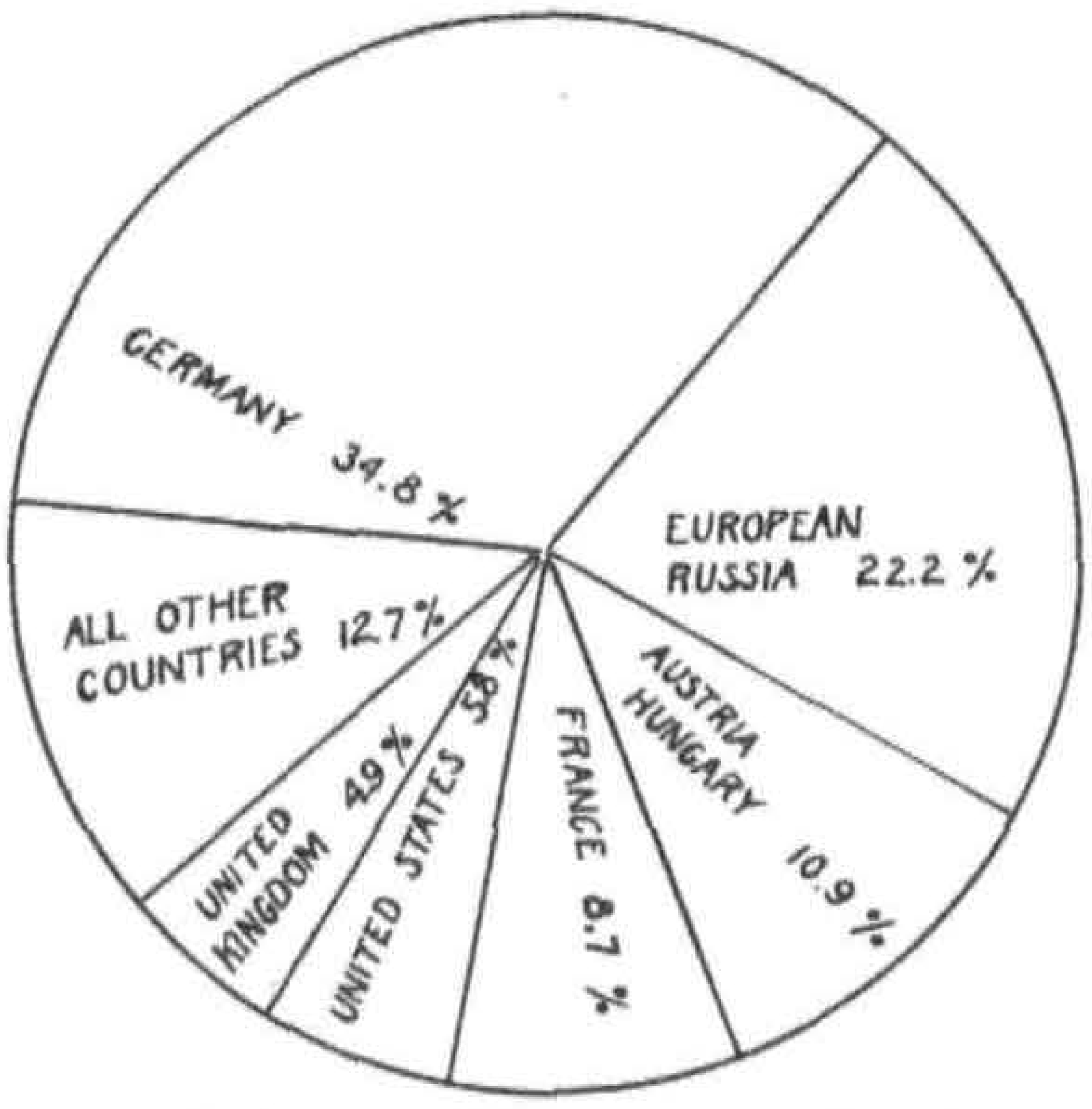


FIG. 238.—Percentage of the world's supply of potatoes produced in the different countries in 1914.

food; and (4) alcohol. Potatoes rank second to the cereals in importance as a food of northern peoples. They are fed to all classes of stock, especially hogs. In the dried state, they have been fed, in Germany, to cattle and horses with good results.

Potato Starch.—The potatoes are first soaked for several hours in water, then washed, and finally reduced to a pulp by rasping machines. The pulp is passed through sieves, which separate the fiber from the liquor containing starch. The liquor is allowed to stand, and during this time white starch settles in layers at the bottom of the receptacle. The

starch is drawn off, purified by allowing it to run over tables, similar to those used in the purification of corn starch (page 186), and finally dried. "Culls" are profitably employed in starch manufacture.

Alcohol.—In Germany, the potato is used extensively for alcohol manufacture. In this country, it is too expensive for this purpose. Here, corn is largely employed in the manufacture of alcohol. The process of converting the starch to alcohol is very similar to that used in the manufacture of alcohol from corn starch.

Production of Potatoes.—The world's output of potatoes in 1912 was 5,872,953,000 bushels. Of this amount, Germany produced 1,844,863,000 bushels, or about 31 per cent. of the total. Russia proper ranked second with a production of 925,775,000 bushels. France third with 552,074,000 bushels, and the United States fourth with 420,647,000 bushels. The five leading potato States in 1919 were Minnesota, New York, Wisconsin, Michigan and Pennsylvania.

SOLANUM MELONGENA (Eggplant, Guinea Squash)

Description.—This species is an annual, erect, branching herb, finally becoming subwoody, 2 to 3 feet tall, woolly or scurfy, and spiny. The *leaves* (Fig. 239) are large, 6 to 9 inches long, sinuately lobed, ovate or ovate-oblong, thick, becoming almost smooth above but remaining densely hairy beneath. The *flowers* are solitary or in small clusters in the axils of branches; the *calyx* is woolly or spiny, the *corolla* purplish and pubescent (Fig. 239). Parthenocarpy has been observed in this species. Artificial pollination is practiced to insure fruit production. The *fruit* is a berry, 3 to 6 inches in diameter, smooth, and varying in color (Fig. 239). Eggplant is a native of India. All cultivated varieties require high temperatures. They are usually transplanted. They are used exclusively as a table vegetable.

Types and Varieties.—Bailey has divided the eggplants into three varieties, as follows:

1. *S. melongena* var. *esculentum* (Common Eggplant).—The plants are tall and stout, the leaves large and thick, and

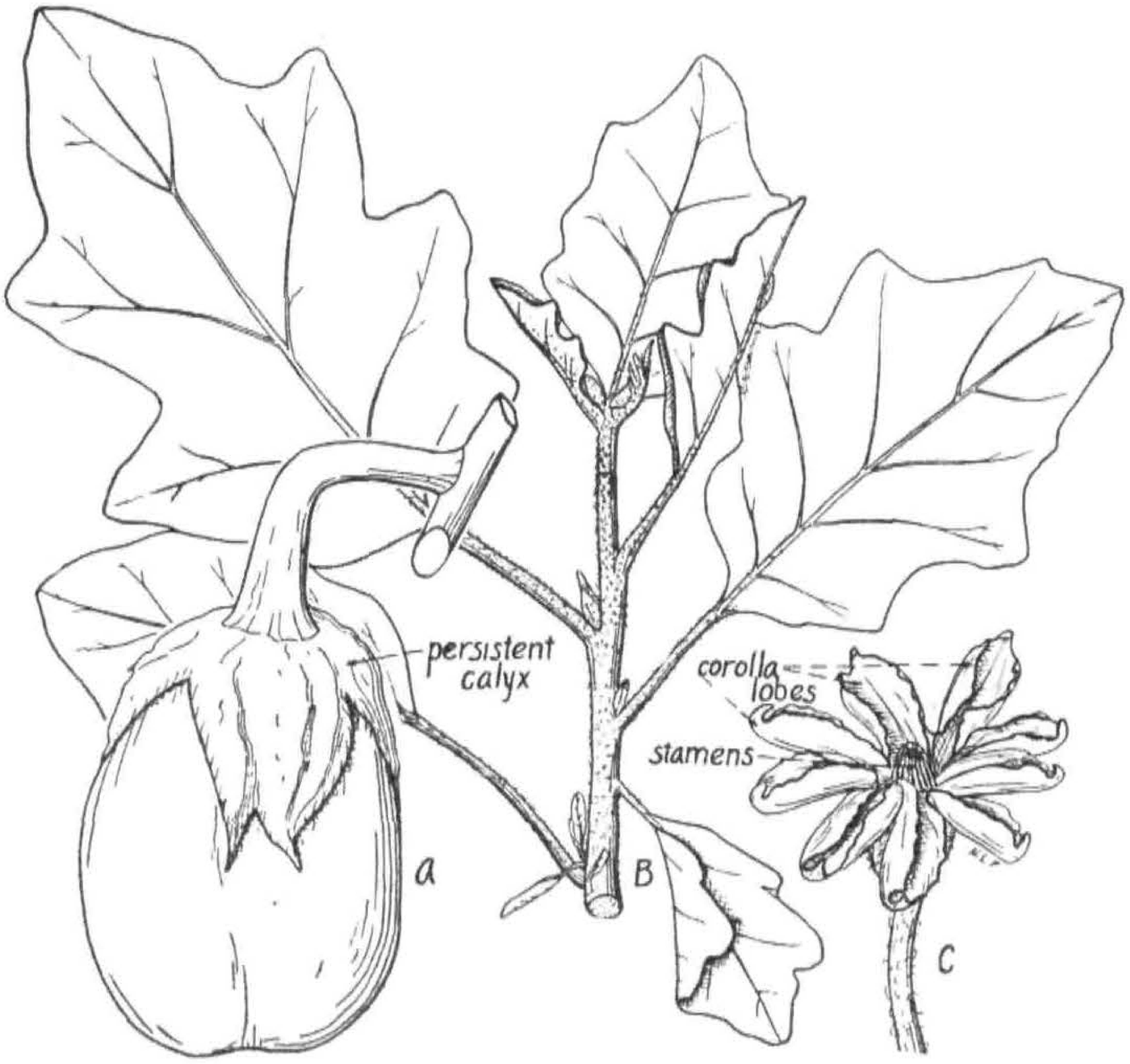


Fig. 239.—Egg plant (Solanum melongena). *A*, mature fruit; *B*, leaves; *C*, single flower.

the fruit large and usually spherical or oblong. There are forms in this group with purple fruit (Black Pekin, New York Improved, Giant Round Purple) and others with white or striped fruit (White Chinese, Long White, White Egg).

2. *S. melongena* var. *serpentinum* (Snake Eggplant).—The plants are medium to tall, the leaves large, and the fruit long and slender.

3. *S. melongena* var. *depressum* (Dwarf Purple Eggplant). The plants are small, weak, and spreading, the leaves small,

the flowers small, and the fruit small to medium, pear-shaped, and purple (Early Dwarf Purple).

LYCOPERSICUM (Tomato)

Habit of Growth, and Stems.—The tomatoes are annual or short-lived perennial, coarse, branching or feebly climbing herbs, that vary in size and form with the species, climate, and methods of culture. The upright growing tomatoes (*L. esculetum* var. *validum*), have a low, stiff, and erect growth form. *L. esculetum* var. *grandifolium* is a tall sort with a few large, entire leaflets. In the currant tomato (*L. pimpinellifolium*), and cherry tomato (*L. cerasiforme*), the branches are usually weak and even trailing in habit. The pear tomato (*L. pyriforme*) has an erect and strong habit of growth.

Roots.—The root system of tomatoes is fibrous and not extensive. It does not penetrate far into the soil and is usually short-lived.

In the transplanting of tomatoes from the seed bed to the garden, it is the practice to allow the seedlings to wilt before they are reset. Under these conditions the fine, tender rootlets, and root hairs are largely destroyed, but the plant promptly throws out a vigorous cluster of new ones. In fact, the new set of roots possesses greater vigor than those on a seedling that has not been allowed to wilt; in the latter case the roots are not injured beyond recovery, and it appears that their recovery prevents the prompt development of new ones.

Leaves.—The leaves are usually alternate, always compound, odd-pinnate, and petioled. In all tomatoes except *L. esculentum* var. *grandifolium* and possibly *L. pimpinellifolium*, the leaflet margin is toothed or lobed.

Inflorescence and Flowers.—The flowers are commonly in raceme-like cymes, or in racemes (as in currant tomato).

However, even in the currant tomato the racemes are often branched at the tip. The *flowers* are perfect, regular, and pendant. The *calyx* is five- to six-parted; the segments are linear or lanceolate, persistent, and increase in size with the development of the fruit. The *corolla* is rotate or wheel-shaped, cleft into usually five, sometimes more, lobes; the tube of the corolla is short. There are five *stamens* (sometimes more) attached to the corolla tube; the filaments are very short, and the anthers open by a longitudinal slit on the inner side; they are elongated, connate or connivent. There is one *pistil* bearing a single style and an *ovary*, which is usually two-celled (more than two-celled in cultivated tomatoes) and has a central, fleshy placenta.

Pollination, Fertilization, and Development of the Fruit.— In the maturing of the flower, the style elongates and pushes the receptive stigma through the tube formed by the anthers. In some instances, this elongation occurs prior to the dehiscing of the anthers, hence eliminating the possibility of self-pollination. Sometimes the anthers shed pollen at the time the stigma is pushed upward, and in the growth of the stigma it rubs against the dehiscing surface of the anthers. Stigmas remain receptive for several days. However, it is known that greenhouse tomatoes do not set fruit well unless artificially pollinated. There are several methods of artificial pollination: (1) jarring the plants at the time of anther dehiscence. (2) collection of pollen on a spoon or glass slide and its removal to other flowers, and (3) emasculation of flowers and dusting of the stigmas, subsequently. Natural cross-pollination seldom occurs.

Extensive experiments made with greenhouse or forced tomatoes showed that self-fertilized blossoms set fruit as well as cross-fertilized ones. Furthermore, there was practically no difference in the appearance or weight of the fruit. and no difference in the number of cells.

Parthenocarpy.—This phenomenon is not at all uncommon in tomatoes. By this is meant the ripening of the fruit without the fertilization of the ovules. Such fruits, of course, possess no seeds capable of germination.

Abnormal Tomatoes.—Munson had found, in crossing tomatoes, that the amount of pollen placed on the stigmas affects the size of the fruit. Two stigmas in the same flower cluster were given different amounts of pollen: one abundant pollen, the other 10 to 20 grains. With plenty of pollen, normal fruit resulted, while with scanty pollen, small and deformed fruit resulted. In the first case, there was abundant seed, while in the latter, only a few seeds. One-sided tomatoes result when pollen falls upon one side of the stigma only. It is undoubtedly commonly true that small and irregular tomatoes are caused by an insufficient supply of pollen.

The Mature Fruit.—The fruit is a true berry (Fig. 240). The wild form of our common garden tomato (*S. esculentum*) has a two-celled fruit with a rather dry placenta. The cells are definite in both number and shape. Cultivated forms of the common garden tomato have a number of cells in the fruit; they are indefinite in both number and shape, and the placenta is exceedingly fleshy. The fewest celled fruits are considered nearest the original type. The pear and cherry tomatoes both have two-celled fruit. The calyx is persistent, adhering to the base of the fruit. The fruit varies in shape, color, and smoothness of surface. The seeds are numerous and small.

Geographical.—All the species in this genus are natives of South America. Dunal, in DeCandolle's Prodromus, gives 10 species of *Lycopersicum;* this number is reduced, however, by some writers. Tomatoes are warm season "vegetables" that require transplanting in central and northern latitudes.

Important Species and Varieties.—There is a difference of opinion whether to consider certain forms of tomatoes

species or only varieties. For example, Bailey recognized but two cultivated species of *Lycopersicum: L. esculentum*, the common tomato, and *L. pimpinellifolium*, the currant tomato. *L. esculentum* is, according to Bailey, divided into the following varieties:

1. *L. esculentum* var. *vulgare*, garden tomato.

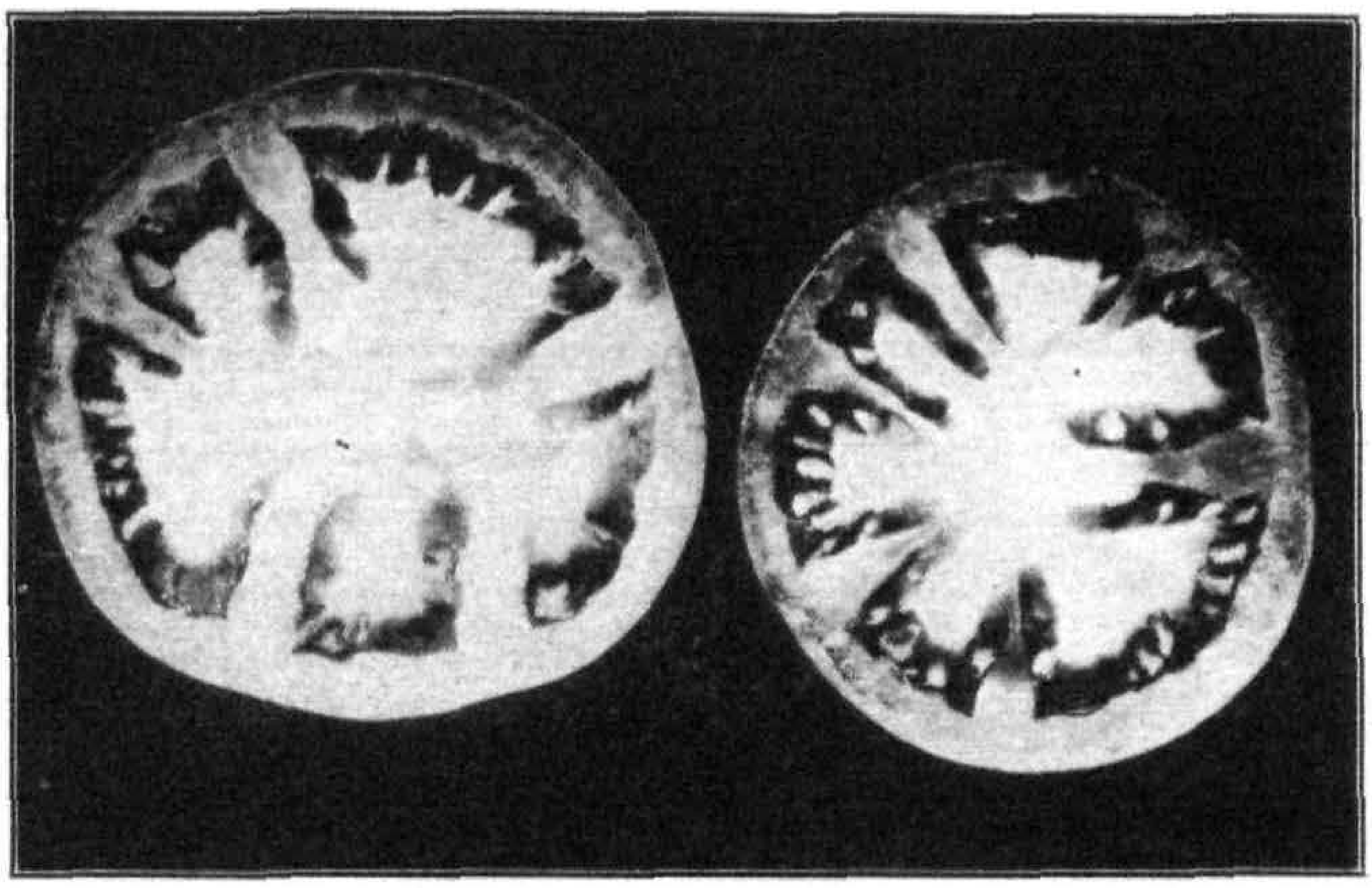


FIG. 240.—Cross-section of mature fruit of cultivated tomato (Lycopersicon esculentum).

2. *L. esculentum* var. *cerasiforme*, cherry tomato.
3. *L. esculentum* var. *pyriforme*, pear or plum tomato.
4. *L. esculentum* var. *validum*, upright tomato.
5. *L. esculentum* var. *grandifolium*, large leaf tomato.

L. pimpinellifolium is not subdivided. On the other hand, Tracy regards as distinct species: *L. pimpinellifolium*, *L. cerasiforme*, *L. pyriforme*, and *L. esculentum*, including under the last the varieties *vulgare*, *validum*, and *grandifolium*.

The above types of tomatoes may be artificially distinguished by the following key; in all instances cultivated forms are understood.

KEY TO TYPES OF CULTIVATED TOMATOES

Fruit in long racemes or branched clusters; berries red, currant-like, *Currant, German, raisin or grape tomato.*
Fruit in short racemes or branched clusters.
  Plants low, stiff, and erect, having much the appearance of a potato plant; Leaves small, curled, *Upright tomato.*
  Plants taller, the branches weaker and more spreading.
    Leaves very large, about two pairs of almost entire-marginal leaflets, *Large-leaf tomato.*
    Leaves of medium size, numerous pairs of leaflets the margins of which are toothed or lobed.
      Fruit pear-shaped, *Pear tomato.*
      Fruit globular or angular, not pear-shaped.
        Fruit globular, smooth, red or yellow, from ½ to ¾ inch in diameter, two-celled, *Cherry tomato.*
        Fruit varying somewhat in shape, surface, and color, larger than preceding, many-celled, *Common garden tomato.*

The common tomato (var. *vulgare*) has undergone considerable modification as the result of cultivation. As compared with the small two-celled fruit, with thin walls and a dry placenta, and in some instances with distinct grooves on the surface, the cultivated forms are larger, many-celled, the walls and placenta are thick and fleshy, and the fruit surface smooth. There are three general groups of the common tomato: fruit angular, fruit apple-shaped, and fruit oblong.

The cherry tomato (var. *cerasiforme*) has small globular, red or yellow two-loculed fruit. The pear tomato (var. *pyriforme*) has small red or yellow, two-loculed pear-shaped fruit. The upright tomato (var. *validum*) looks much like the potato plant in its growth habit. The large-leaf tomato (var. *grandifolium*), of which the Mikado may be taken as a type, is distinguished from the other varieties by its large leaves with only a few (normally two) pairs of leaflets.

Closely Related Forms.—The husk tomato (*Physalis pubescens*) and the strawberry tomato (*Physalis pubescens* and *P. alkekengi*) are distinguished from *Lycopersicum* spp. in that the calyx becomes enlarged, inflated, and

entirely covers the small berry. The fruit is esteemed by some for preserving, or making pies, or for eating raw.

The tree tomato (*Cyphomandra betacea*), a tropical plant, has a fruit similar in taste, at least, to that of the common tomato. This plant also belongs to the Solanaceæ, but may be distinguished from *Lycopersicum* by its woody habit of growth.

History.—The tomato is still found in the wild state in South America. The Spanish explorers carried the fruit to southern Europe where it was used as a food long before it was eaten by the people of northern Europe. It was early known in England and America as the "Love Apple." A prejudice against the tomato existed for a long time, no doubt due to its alliance with the nightshades. Now, however, it is a favored article of diet, and from 500,000 to 600,000 acres are devoted to its growth annually in the United States and there are as many as 175 different varieties offered by seedsmen.

Uses.—Tomatoes are commonly used, fresh or canned, as a table vegetable. Large quantities are made into catsup. Such varieties as Red Plum, Yellow Plum, Red Pear-shaped, and Red Cherry, are used quite extensively for pickling. The chief canning variety is Stone; and the best known market varieties are Globe, Earliana and Bonny Best.

It has been shown that the large amounts of tomato refuse which accumulate each year at tomato-pulping factories can be reduced to a fixed oil and meal. The oil expressed from the seeds may be used as an edible oil or as a soapoil, or it may be made into a drying oil. The meal is of value as stock feed.

CAPSICUM ANNUUM (Peppers)

Description.—This species is either an annual or biennial herb, 2 to 5 feet tall, and sometimes partly woody at the base, In temperature regions, the plant is cultivated as an annual, while in warmer climates it is often biennial. The *leaves* are

ovate and entire. The *flowers* (Fig. 241) are solitary, or in twos or threes. The *calyx* is five-lobed, truncate, obconical, cup-shaped or funnelform. The *corolla* is white, rotate, usually five-lobed, with the lobes valvate. There are five *stamens*, sometimes six or seven, attached near the base of the corolla; the bluish anthers dehisce longitudinally. The *ovary* is usually two-celled, rarely three-celled, and bears a thread-like style, and numerous ovules. The *fruit* (Fig. 242) is a berry, red or green in color, and short cylindrical or globular in shape. There are many seeds in each fruit.

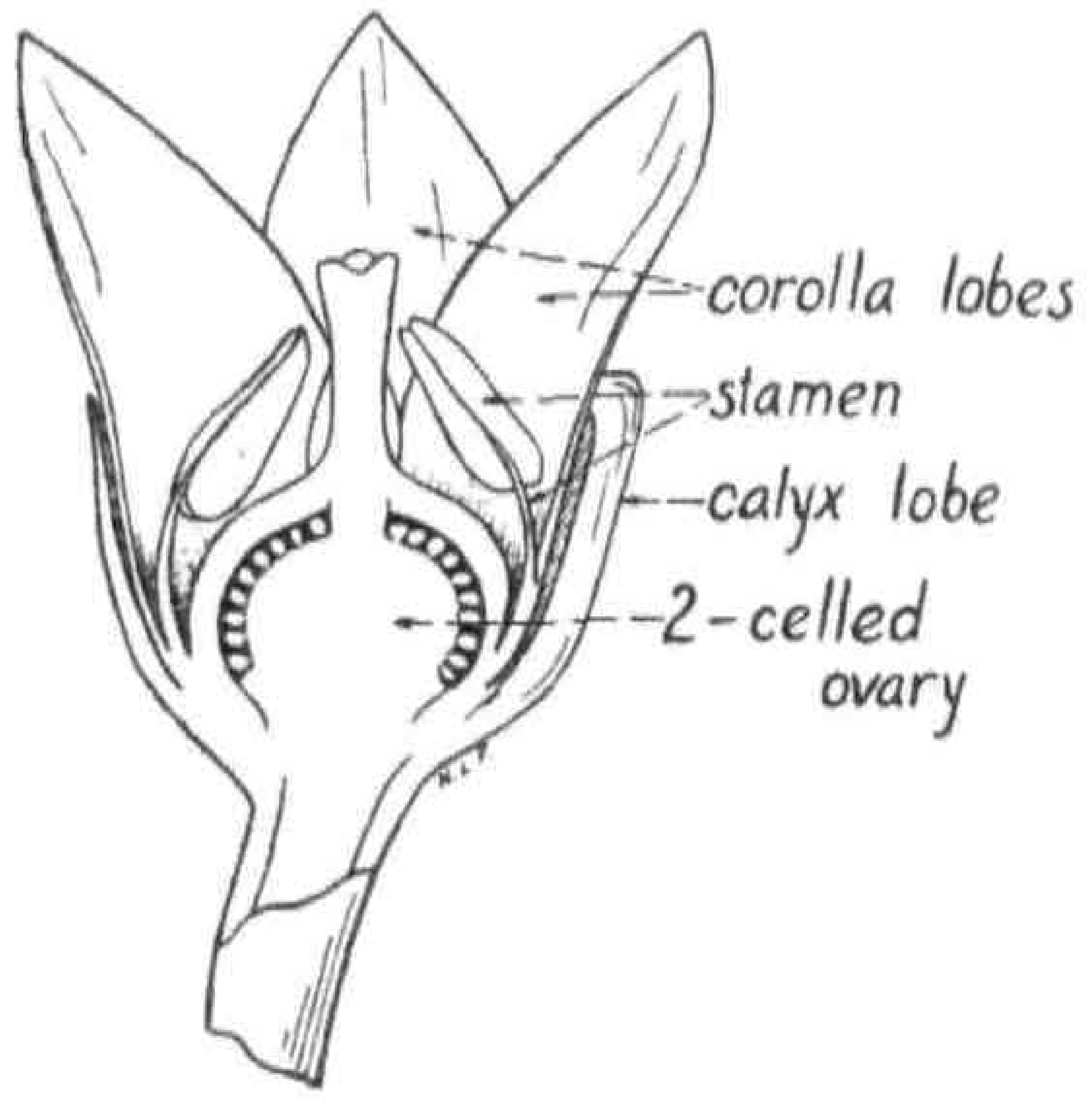


FIG. 241.—Median longitudinal section of pepper flower (Capsicum annuum). × 2.

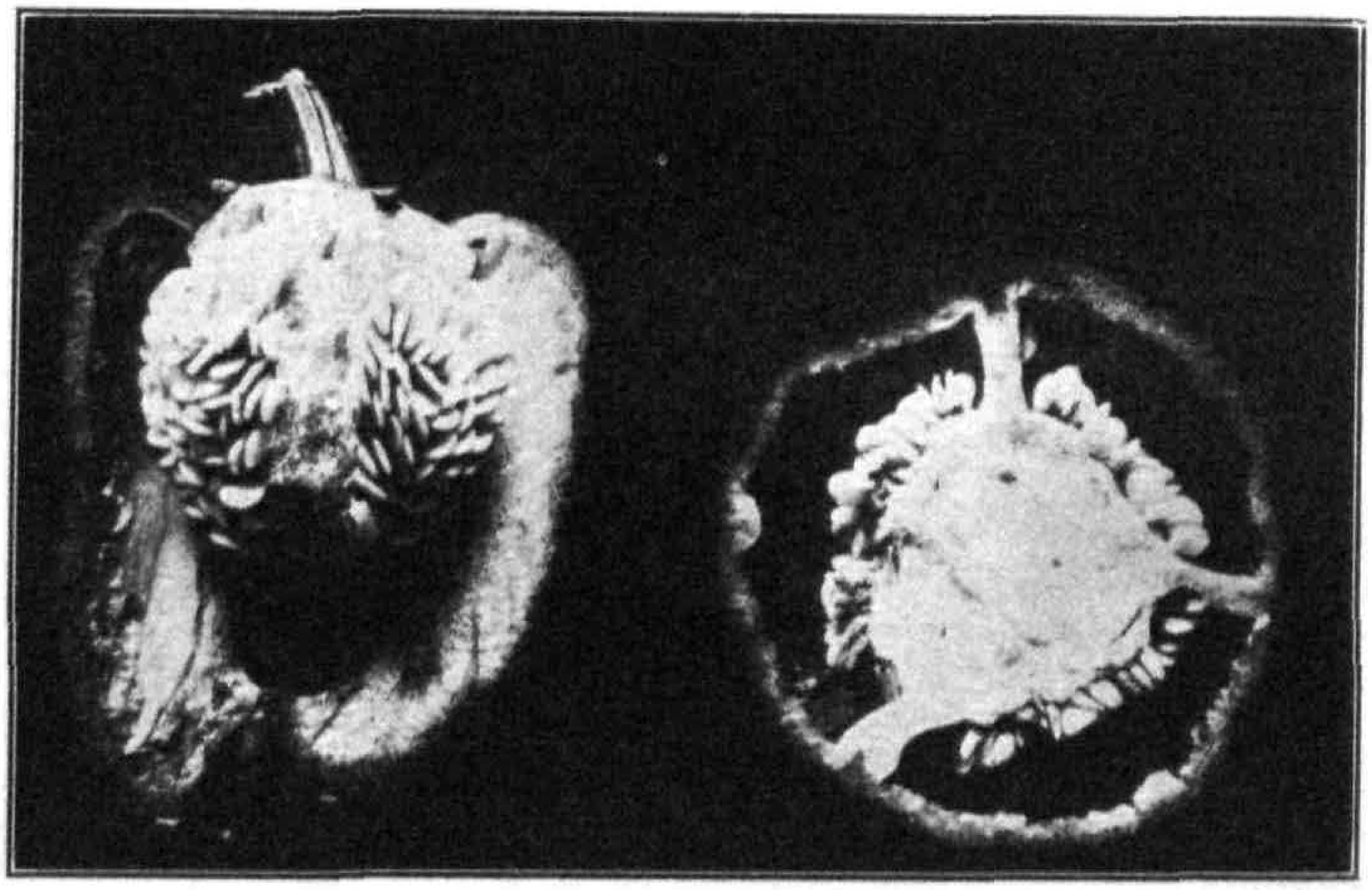


FIG. 242.—Cross and lengthwise sections of the fruit of pepper (Capsicum annuum).

Geographical.—This species has never been found wild. But it is quite well established that the entire genus *Capsicum* had its origin in tropical America.

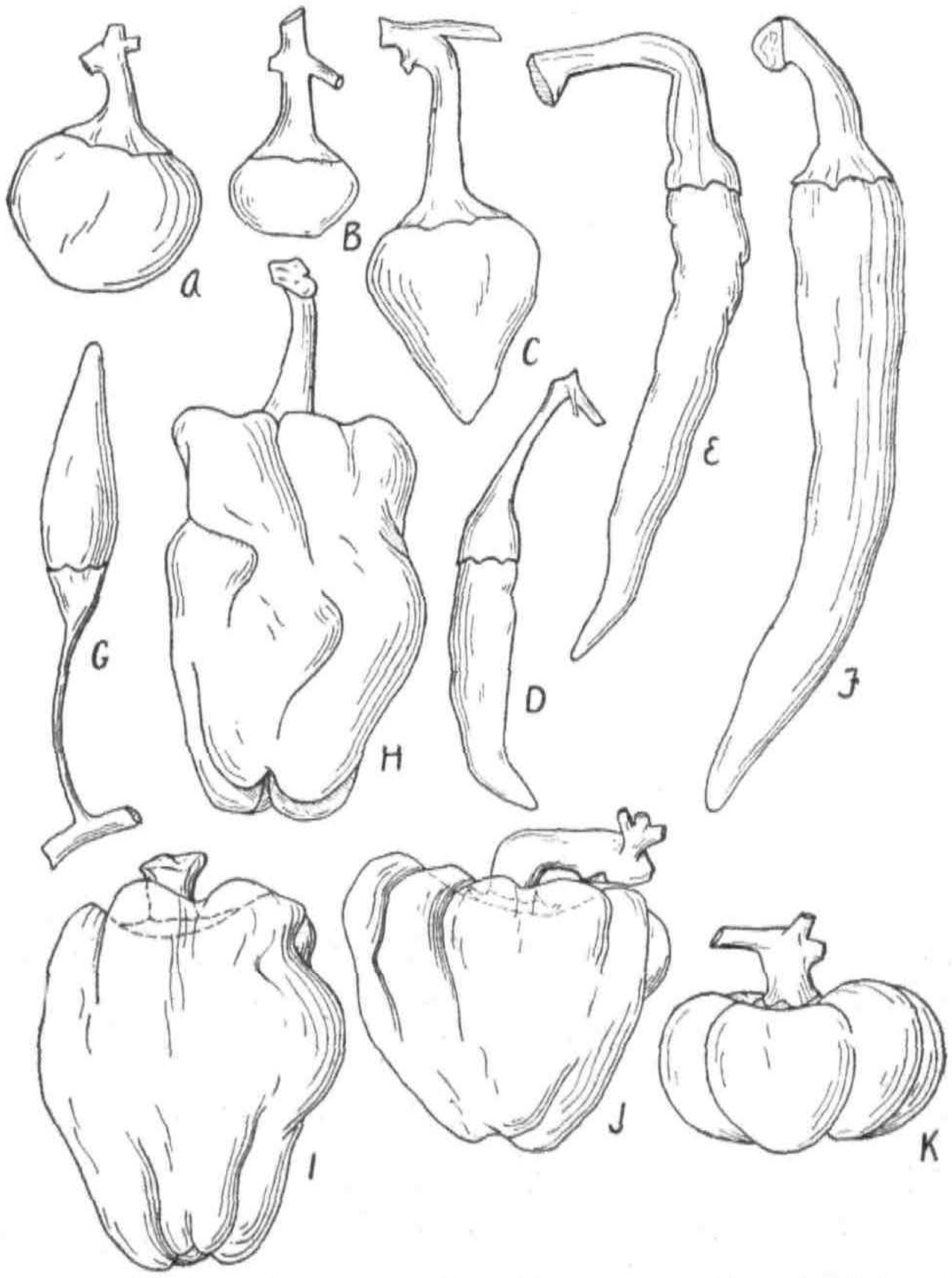


FIG. 243.—Fruits of peppers (Capsicum annuum). *A*, Oxheart (C. annuum cerasiforme); *B*, Cherry (C. annuum cerasifera); *C*, Celestial (C. annuum abbreviatum); *D*, Chilli (C. annuum acuminatum); *E*, Long Cayenne (C. annuum acuminatum); *F*, Long Yellow (C. annuum longum); *G*, tabasca (C. annuum conoides); *H*, Sweet Spanish (C. annuum grossum); *I*, Ruby King (C. annuum grossum); *J*, Bell (C. annuum grossum); *K*, Squash (*C.* annuum grossum). (*After Irish.*)

The temperature requirements of peppers are similar to those of eggplants and tomatoes. Their season of growth is so long that they are unable to produce a full crop before frost, except in the Southern States, unless started under glass.

Other Species.—The only other species of *Capsicum* of any importance is *C. frutescens*. This is a shrubby perennial 6 to 10 feet high. Its fruit does not ripen well in northern latitudes. The fruit is red, small, and is often called "bird pepper."

Types.—Irish, in his excellent monograph of the genus *Capsicum*, places the numerous commercial varieties into seven types or botanical varieties (Fig. 243). The following key to these types is taken (verbatim) from this work.

KEY TO BOTANICAL VARIETIES OF CAPSICUM ANNUUM

Fruit oblong-linear.
- Calyx usually embracing base of fruit.
  - Fruit usually less than 1½ inches long; peduncles about as long or longer, *C. annuum conoides* (Coral Gem, Tabasco, Cayenne, Orange-red Cluster).
  - Fruit usually more than 1½ inches long; peduncles shorter.
    - Leaves and fruit fascicled; fruit erect, *C. annuum fasciculatum* (Red Cluster, Yellow Cluster).
    - Leaves and fruit not fascicled, *C. annuum acuminatum* (Chilli, Long Cayenne, Nepal Chili).
- Calyx not usually embracing base of fruit, except in the Ivory Tusk variety, *C. annuum longum* (Black Nubian, Long Red, County Fair, Cardinal, Long Yellow, Ivory Tusk).

Fruit oblate or oblong, truncated, deeply lobed, furrowed and wrinkled; flesh mild, $\frac{1}{12}$ to ⅛ inch thick, *C. annuum grossum* (Monstrous, Sweet Spanish, Bell, Sweet Mountain, Golden Dawn, Ruby King, Brazilian Upright, Golden Upright, Squash).

Fruit subconical, ovate or elliptical, slightly longer than broad, ¾ to 2 inches long; calyx not embracing base, *C. annuum abbreviatum* (Celestial, Etna, Kaleidoscope, Red Wrinkled, Princess of Wales).

Fruit generally smooth, oval, spherical, cherry or heart-shaped, ⅜ to 1½ inches in diameter; calyx seated on the base, *C. annuum cerasiforme* (Little Gem, Cherry, Oxheart).

Composition.—All varieties of pepper are more or less pungent. The principle which imparts the pungent taste is a crystalline nitrogenous compound called *capsaicin*. In the smaller peppers (Coral Gem, Tabasco, Chilli, Cayenne, Cherry) the pungency is in the pericarp as well as in the placenta and seed. In larger varieties (Squash, Bell, Sweet

Mountain), the pungent taste is located for the most part about the seeds, while the fleshy pericarp is "mild."

Uses.—Medicinally, the red pepper is used in a great variety of ways. Probably its most important use is as a condiment, Cayenne Pepper being the common form. This is made by grinding up the entire fruit to a fine powder. Pepper sauce is the unground fruit preserved in brine or strong vinegar. Tabasca Pepper and Tabasca Catsup are examples of this. Chilli con carne is a mixture of small, finely ground peppers and meat. Peppers are commonly used in tamalas, also in pickles and salads, while bell-shaped and squash varieties are used as mangoes. Some varieties, such as Little Gem and Prince of Wales, are grown for ornamental purposes.

NICOTIANA (Tobacco)

Most representatives of this genus are tall, stout herbs. Several (as *N. glauca* and *N. tomentosa*) grow to a height of 10 feet or more. *S. wigandioides* is half-shrubby. They are annual or perennial in habit, and for the most part sticky-pubescent; they have a strong odor, and narcotic, poisonous properties.

Leaves.—The leaves are simple, alternate, mostly large, entire or wavy along the margin, petioled (in *N. glauca*), or sessile and decurrent.

Inflorescence and Flowers.—The *inflorescence* is a terminal raceme or panicle. The *flowers* are large and vary in color: white, yellowish-white, greenish, purplish, or rose. The *calyx* is synsepalous, five-cleft, and usually persists in the fruit. The *corolla* is salverform or funnelform, five-lobed, and the tube is longer than the limb. There are five *stamens* attached to the corolla tube; the filaments are slender, and the anthers split lengthwise. The two-celled *ovary* bears a single, slender style, and a capitate stigma.

Fruit.—The *fruit* is a two-celled capsule bearing numerous very small seeds; it splits into two or four valves at maturity.

Geographical Distribution and Economic Importance.—The genus includes about 50 species, mostly of the American tropics. A number of species are grown for ornamental purposes. *N. tabacum* (tobacco) is the only one of great commercial importance.

NICOTIANA TABACUM (Tobacco)

Roots, Stems.—The common tobacco is a strong annual plant, 3 to 5 feet tall. The *root system* is quite extensive and fibrous. The American varieties bear large, thick *stems* which are hairy and sticky. In tobacco culture it is customary to "top" the plants, that is, remove the flower stalks, so that a considerable portion of the food supply which would normally go to flower and fruit production may be directed to leaf growth. Topping stimulates the production of "suckers" (new shoots). They must be removed before reaching any great size, as the quality of the leaves is damaged by their growth. The "one-sucker" type of tobacco is one that throws out one or only a few suckers.

Leaves.—There is great variation in the shape, color, texture, and number of leaves. In cigar-wrapper tobaccos, the leaves are thin, fine in texture, and small-veined. The leaves of plug and pipe tobaccos are usually coarser, thicker, and tougher. The leaves are sessile, decurrent, and either narrow or broad, most commonly lanceolate or ovate, and pointed. The number of leaves on a plant, which is, of course, important commercially, is different in the various types and also varies considerably from plant to plant in the same type. In the Sumatra cigar-wrapper tobacco the leaves range from 16 to 30, in the White Burley plug tobacco from 10 to 18, and in the Zimmer Spanish cigar-filler tobacco from 14 to 20.

Tobacco plants are sometimes grown in the shade of tents, which condition makes a larger and thinner leaf with less vascular tissue. The leaf is thus improved for wrapper purposes. The chief effect of shade is to reduce the rate of transpiration. There is evidence that transpiration rate is the important factor determining the development of vascular tissue.

"Grain" in Tobacco Leaves.—"Grain" of tobacco appears as small pimple-like projections or papillæ over the cured leaf. The papillæ vary in size from about 1 millimeter to microscopic dimensions. Each grain body consists of from one to several leaf cells filled with crystalline substance. The grain is composed chiefly of calcium, with some potassium and magnesium, in combination with citric and malic acids. Grain of tobacco is developed during the process of curing and fermentation. It is a character that the buyer takes into consideration when he selects tobacco.

Inflorescence and Flowers.—The *inflorescence* is a terminal panicle. The *flowers* (Fig. 244) are about 2 inches long, and pink, yellow, purple or white. The tubular or bell-shaped *calyx* is four- to five-cleft. The tube of the *corolla* is swollen, its lobes spreading and pointed.

Pollination and Fertilization.—Tobacco flowers bear nectaries and are visited by insects. Hence, cross-pollination is probably somewhat frequent. Moreover, observations and experiments show that the flowers are self-fertile—that they will produce viable seed when close-fertilized. The earlier blossoms of an inflorescence are more commonly close-fertilized than are the later ones of the same inflorescence. That the tobacco plant is, in all probability, naturally close-fertilized, is borne out by the fact that self-fertilization (inbreeding) under control has not resulted in a loss of vigor.

Fruit.—The *fruit* (Fig. 244) is a two- to four-valved capsule, bearing numerous small seeds. A single plant may produce as many as a million seeds.

Geographical.—This species is indigenous to tropical South America. Its varieties are now in cultivation throughout subtropical and even temperate

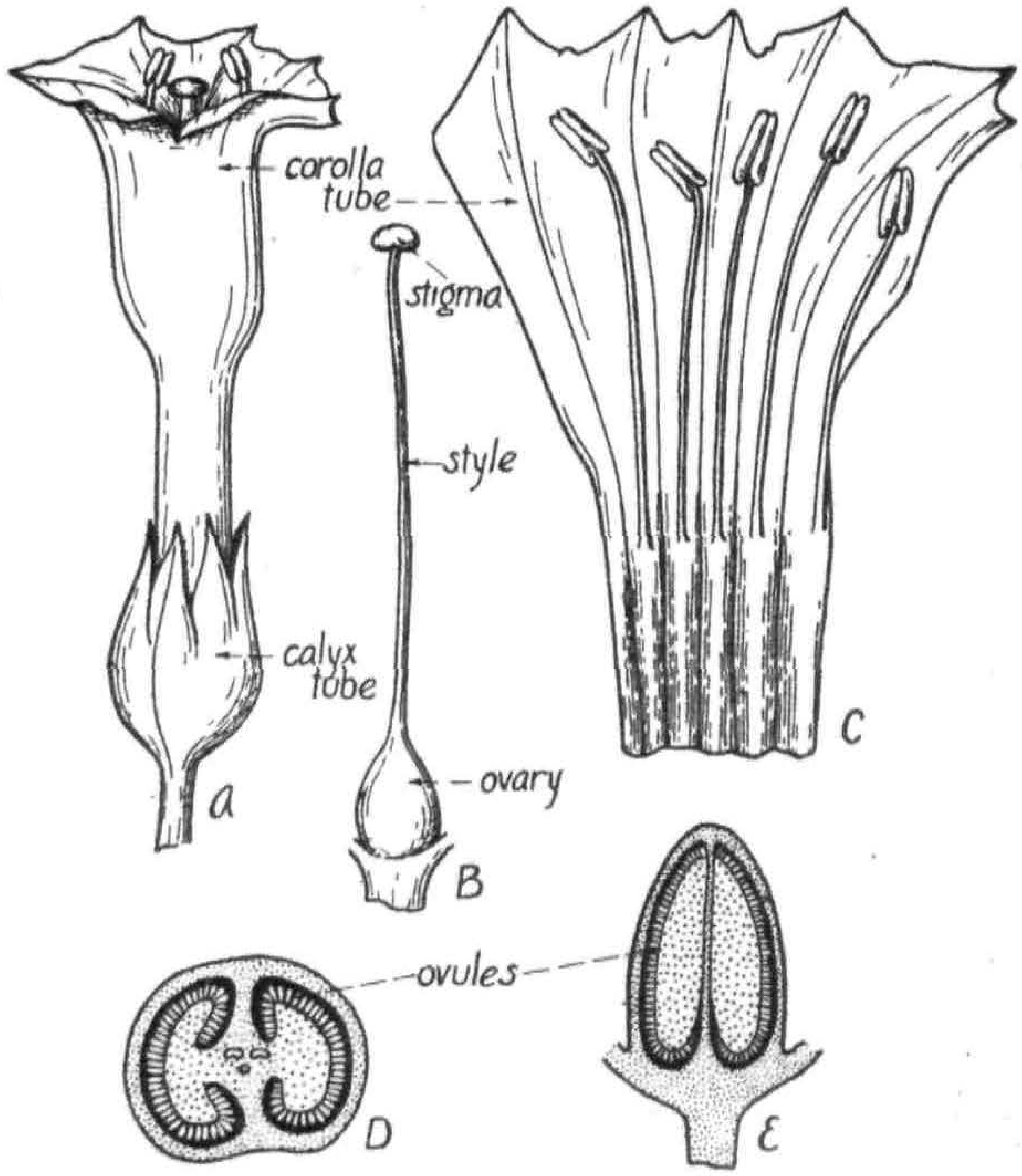


FIG. 244.—Tobacco (Nicotiana tabacum). *A*, flower; *B*, pistil; *C*, corolla cut open and spread out flat; *D*, cross-section of young fruit; *E*, lengthwise section of young fruit. (*After Strasburger.*)

climates. It occasionally escapes from cultivation and runs wild. It is grown commercially only in the humid sections of this country.

Closely Related Species.—There are a number of species of Nicotiana which resemble *N. tabacum* somewhat, and there are several species belonging to other genera besides *Nicotiana* that go by the name "tobacco."

N. rustica is a "wild tobacco" that was cultivated by the Indians. It is a tall annual with petioled leaves. *N. quadrivalvis* is another plant cultivated by the Indians for tobacco. It is native to the region extending from Texas

to California and Oregon. *N. persica* yields Persian tobacco. "Australian tobacco" is the leaf of *Duboisia hopwoddii*, a species of *Solanaceæ*. "Indian" or "wild tobacco" is a name often given to *Lobelia inflata*, the dried leaves and tops of which are officinal. It is a member of the bellflower family, *Campanulaceæ*. *Arnica alpina*, a composite, is sometimes known as "mountain tobacco." The most popular ornamental *Nicotiana* is *N. alata*. In it the flowers are white, open at night and closed in the daytime.

Types and Varieties.—There are two general types of tobacco grown in this country:

1. *Cigar type*, the leaves of which are made into cigar wrappers, binders and fillers. The leaves are thin and of fine texture. Common varieties are Sumatra, Connecticut Havana, Connecticut Broadleaf, Cuban, Zimmer Spanish, and Little Dutch.

2. *Export and manufacturing type*, the leaves of which are used to make smoking tobacco, chewing tobacco, cigarettes, and snuff. The leaves, as compared with those of the preceding type, are thicker, tougher, and of coarser texture. Popular varieties are White Burley, North Carolina Bright Yellow, Maryland Smoking, Yellow Mammoth, Pryors and Orinocos. Export and manufacturing tobaccos are produced on soils and in sections of the country different from the cigar types. The physical and chemical properties of the soil have a marked influence on the quality of the tobacco leaf. Light, well-drained soils, in which there is not too much organic matter, produce a leaf of mild flavor and fine texture. On the other hand, heavy, rich soils produce a leaf of stronger flavor and coarser texture.

Composition.—The tobacco plant is a heavy feeder. It removes large quantities of nitrogen, potash, and phosphoric acid from the soil. Consequently, the plant is rich in these valuable plant nutrients. In fact the leaves and stalks make excellent fertilizers, and are so used in tobacco sections.

Curing Tobacco.—This process consists in removing the moisture in the leaves and stems in such a manner as to

produce a uniform color and texture in the leaves. Artificial heat was first employed in the curing of tobaccos in 1812. Wood fires were used up to the year 1828, about which time, flues, and charcoal fires came into use. Flue-curing entirely replaced charcoal fires in 1865. Flue-curing produces a bright yellow leaf. The green tint is obtained by harvesting the leaf before it is fully ripe. The dark export tobaccos are cured with open hard-wood fires. Light tobaccos may be air-cured, and such are used for pipe smoking, and cigarettes. White Burley tobacco, so highly prized for twist and plug chewing tobaccos, is usually air-cured. The yellow and mahogany tobaccos are cured by flues. The process takes about four days. The broad leaf and Havana seed leaf varieties of the Connecticut Valley are air-cured. They are domestic cigar tobaccos. Curing is often carried on in specially constructed barns with horizontal ventilators. It usually takes about two months to air-cure tobacco, and less time if artificial heat is used. After the leaves have been left hanging for a long time, they are packed closely in boxes, where they are left undisturbed for several months. When warm weather sets in, a process of *fermentation* is set up in the cases, during which process certain important changes take place. Fermentation may be brought about after a shorter period of drying than is used in the preceding method, by placing the leaves in piles in a warm, moist atmosphere. When the temperature reaches 125° to 130°F., the piles are opened and heaped up again. The piles are thrown down and remade a number of times, until the leaves are ready for the market. During fermentation the leaf undergoes a number of changes such as a decrease in nicotin, an increase in alkaline reaction, in ammonia, and nitrate, a loss of water and sugar, and a change in the texture, color and flavor. It is not known positively whether fermentation is a result of oxidation by free oxygen of the air, or of bacterial activity, or is due to the action of enzymes.

The Tobacco Industry.—From colonial days the tobacco industry has been an important one in this country. It is interesting to note that tobacco was made legal tender in 1732 in Maryland, where a pound was 1 penny, and where it was used for the "payment of all debts, including customs, dues, salaries of State officers and ministers of the gospel." In 1777 the tax levy for the county and city of Baltimore was 172 pounds of tobacco per poll.

Virginia and Maryland were long the only tobacco-producing States. The industry has now spread to other States, and the production in 1919 is shown in the following table:

TOBACCO: ACREAGE, PRODUCTION, AND TOTAL FARM VALUE, BY STATES, 1919

State	Acres	Pounds
Kentucky	634,038	506,150,592
North Carolina	459,011	280,163,432
Virginia	225,504	102,391,226
Tennessee	138,561	112,367,567
South Carolina	103,496	71,193,072
Ohio	75,789	64,420,472
Pennsylvania	42,799	55,965,851
Wisconsin	41,465	52,454,246
Maryland	28,550	17,336,859
Connecticut	26,930	42,193,196
United States	1,864,080	1,372,993,261

The United States leads all other countries in the production of tobacco. In 1914, Japan ranked second to the United States, but its output was only about 10 per cent. of that in this country.

References

APPLEMAN, C. O.: Physiological Behavior of Enzymes and Carbohydrate Transformations in After-ripening of the Potato Tuber. Bot. Gaz., 52: 306–315, 1911.

ARTSCHWAGER, E. F.: Anatomy of the Potato Plant, with Special Reference to the Ontogeny of the Vascular System. Jour. Agr. Res., 14: 221–252, 1918.

BARNES, J.: The Potato (Solanum Tuberosum): Its History, Microscopical Characters, and Structure. Ann. Rep. Trans. North Staffordshire Field, cl, 1902–03, pp. 96–106.

BERNARD, NOEL: Sur la tuberculization de la pomme de terre. Compt. Rend. Acad. Sci. (Paris), 132: 355–357, 1901.

BERTHAULT, PIERRE: Recherches botaniques sur les varieties cultivees du *Solanum tuberosum* et les especes sauvages de *Solanum tuberiferes* voisins. Ann. Sci. Agron., 28: 1–59, 87–143, 173–216, 248–291, Paris, 1911.

CLARK, C. F.: Development of Tubers in the Potato. U. S. Dept. Agr. Bull. 958: 1921.

FITCH, C. L.: Productiveness and Degeneracy of the Irish Potato. Colo. Agr. Exp. Sta. Bull. 176: 1–16, 1910.

Indentification of Potato Varieties. Ia. Agr. Ext. Dept. Bull. 20: 1–32, 194.

FLETCHER, S. W., and GREGG, O. I.: Pollination of Forced Tomatoes. Mich. Agr. Exp. Sta. Spec. Bull. 39: 2–10, 1907.

Pollination of Forced Tomatoes. Mich. Agr. Exp. Sta. Spec. Bull. 39: 294–301, 1907.

GABLE, C. H.: The Wild Tomato. Jour. Hered., 6: 242, 1915.

GILMORE, JOHN W.: Quality in Potatoes. Cornell Agr. Exp. Sta. Bull. 230: 503–525, 1905.

GOODSPEED, T. H.: Parthenogenesis, Parthenocarpy and Phenospermy in Nicotiana. Univ. Calif. Pub. Bot., 5: 249–272, 1915.

HALSTEAD, B. B.: Notes upon Stamens of Solanaceæ. Bot. Gaz., 15: 103–106, 1890.

HECKEL, E.: Sur l'origine de la pomme de terre cultivee et sur les mutations gemmaires culturales des Solanum tuberiferes sauvages. Ann. Fac. Sc. Marseille, 1907, 82 pp.

IRISH, H. C.: A Revision of the Genus Capsicum with Especial Reference to Garden Varieties. 9th Ann. Rep. Mo. Bot. Gard., 53–110, 1898.

JONES, DONALD F.: Natural Cross-pollination in the Tomato. Science, n. s., 43: 509–510, 1916.

KLEMT, F.: Über den Bau und die Entwickelung der Solanaceenfruchte. Berlin, 1907.

MAGROU, H.: Symbiosis and Tuberization in Potato. Compt. Rend. Acad. Sci. (Paris), 158: 50–53, 1914.

MIDDLETOWN, R. MORTON: Solanum Tuberosum L., and Its Allies. Jour. Bot., 47: 228, 1909.

RABAK, FRANK: The Utilization of Wasted Tomato Seeds and Skins. U. S. Dept. Agr., Bur. Plant Indus. Bull. 632: 1:14, 1917.

REED, T.: The Anatomy of Some Tubers. Ann. Bot., 24: 537–548, 1910 (Potato and Jerusalem artichoke).

RENDLE, A. B.: Production of Tubers within the Potato. Jour. Bot., 31: 193–195, 1893.

RIDGWAY, CHARLES S.: Grain of the Tobacco Leaf. Journ. Agri. Research, 7: 269–288, 1916.

SCHULTZ, E. S., and FOLSOM, DONALD: Leafroll, Net-necrosis, and Spindling-sprout of the Irish Potato. Jour. Agr. Res., 21: 47–80, 1921.

STEWART, F. C.: Observation on Some Degenerate Strains of Potatoes. N. Y. Agr. Exp. Sta. Bull. 422: 319–357, 1916.

STUART, WILLIAM: Group Classification and Varietal Descriptions of Some American Potatoes. U. S. Dept. Agr. Bull. 176: 1–56, 1915.

The Potato: Its Culture, Uses, History and Classification. J. B. Lippincott Co., 1923.

WITTMACK, L.: Die Stammpflanze unserer Kartoffel. Landw. Jahrb., 38: 551–605, 1909.

Studien über die Stammpflanze der Kartoffel. Ber. Bot. Gesell., 27: 28–42, 1909.

CHAPTER XXXIX

CUCURBITACEÆ (Gourd Family)

There are about 650 species of cucurbits, mainly in tropical regions. All cultivated cucurbits are easily injured by frost, and are distinctly warm season crops.

A number of species are of economic importance. Chief of these are the pumpkin, squash, watermelon, muskmelon, and cucumber. The wild cucumber (*Echinocystis lobata*) and the star cucumber (*Sicyos angulatus*) are sometimes planted as ornamental vines. The squirting cucumber (*Ecballium elaterium*) is a fleshy herb containing a cathartic and poisonous principle, elaterin, the main ingredient of elaterium.

The members of this family are commonly known as "cucurbits." The majority of them are annual, climbing or trailing herbs, with tendrils, but often reaching a large size.

Stems and Leaves.—The stems are hollow and usually covered with stiff hairs. The leaves are large, alternate, petioled, heart-shaped, palmately lobed or dissected. The tendrils arise as a rule in the axils of leaves. The same tendril may be dextrorse and sinistrorse at different points along its axis and may be simple or forked.

Flowers.—The flowers (Figs. 246 and 247) are axillary, either solitary, paniculate, or rarely racemose or subumbellate. They are monœcious, or diœcious commonly white or yellow, rarely blue or red. The *calyx* forms a tube which is adnate to the inferior ovary; its limb is tubular or campanulate, and usually has five imbricated lobes. The *corolla* is five-lobed, usually sympetalous, sometimes parted to the base,

inserted on the limb of the calyx, and rotate or campanulate. The *stamens* (Fig. 247) are five in number, but they often grow together so that there are apparently three. In case there are three stamens, two of them are broader than the third; the two broad stamens have two-celled anthers, the

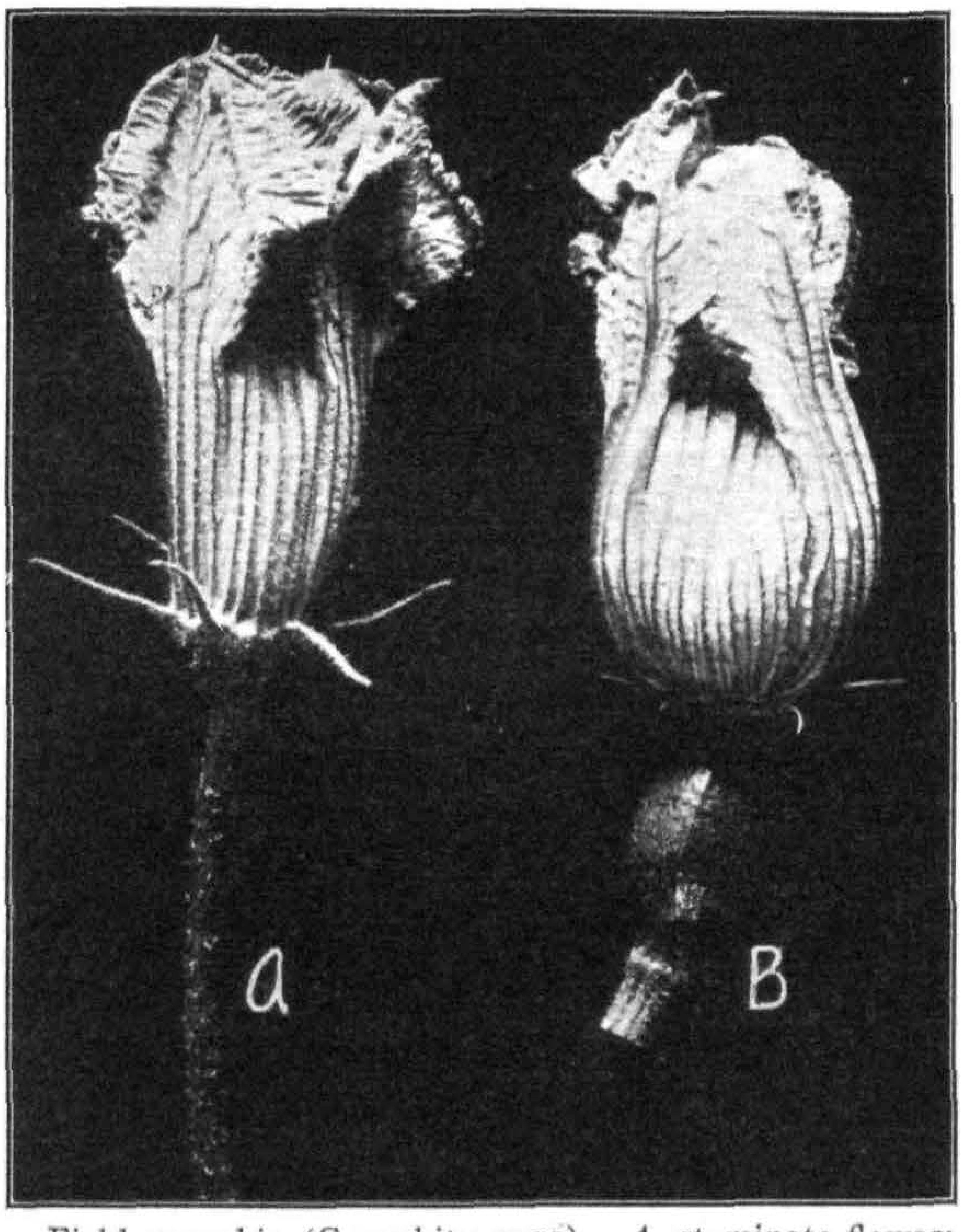


FIG. 246.—Field pumpkin (Cucurbita pepo). *A*, staminate flower; *B*, pistillate flower.

other has a one-celled anther, thus making in all five anther cells to the andrœcium. The filaments are short, often united, and tipped by the worm-like pollen sacs. The *ovary* (Fig. 248) is inferior, one- to three-celled and usually has numerous seeds in each cell or locule; the style is terminal, simple or lobed.

Fruit.—The *fruit* is a pepo, usually indehiscent, or in some cases (*Micrampelis*, *Cyclanthera*) dehiscent at the apex or bursting irregularly. In many instances (watermelon, pumpkin, squash), the fruit is of enormous size. The outer part

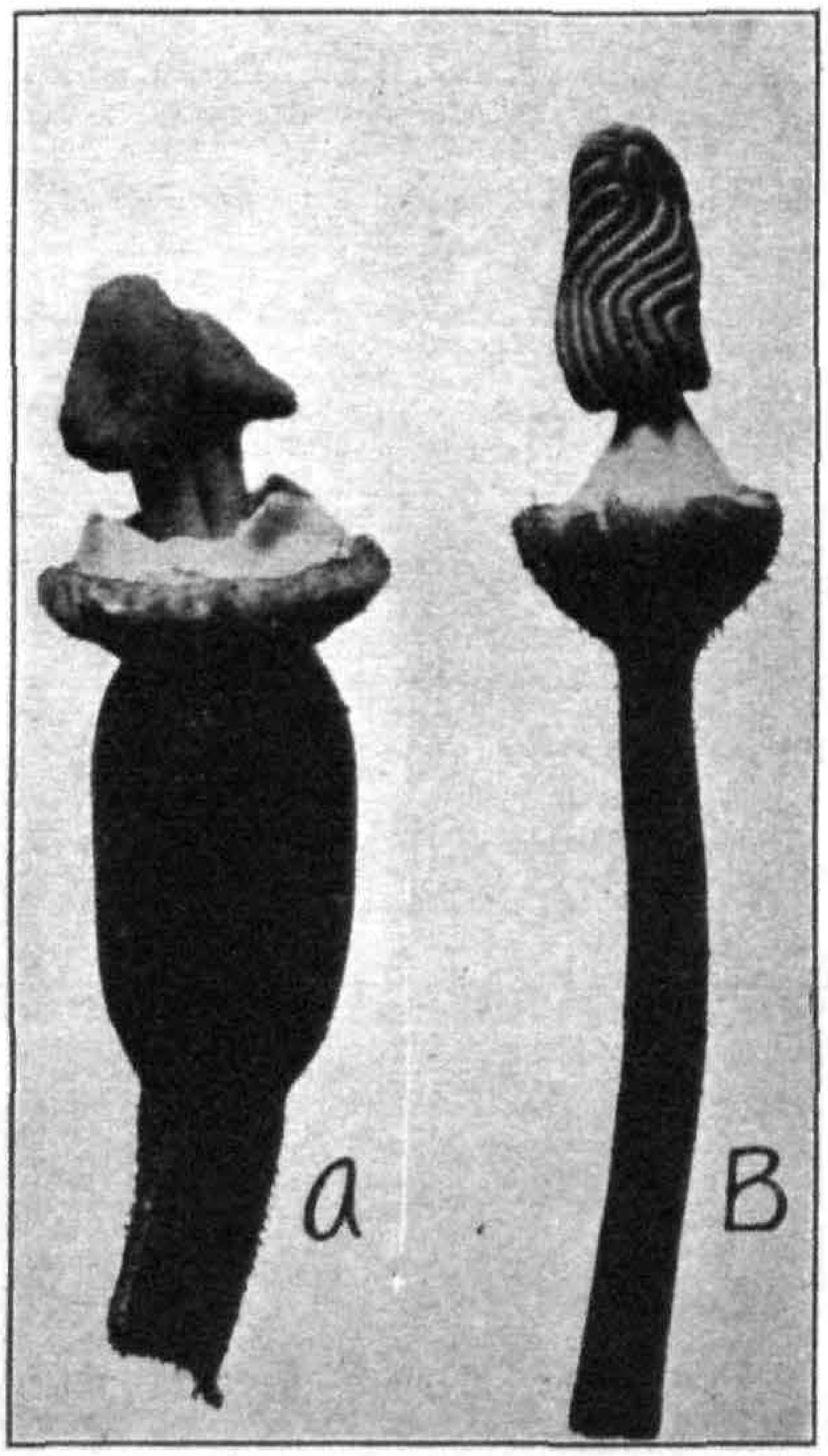


FIG. 247.—Field pumpkin (Cucurbita pepo). *A*, pistillate flower; *B*, staminate flower; both with perianth removed.

of the fruit is receptacle which has become attached to the exocarp. The flesh of the fruit is chiefly mesocarp and endocarp. Seeds are usually abundant, flat, and without endosperm.

Germination of Cucurbit Seeds.—The cotyledons are epigean in all the common members of the Cucurbitaceæ. There are a few hypogean forms, such as *Megarhiza cali-*

fornica and *Sicyosperma gracilis*. The first portion of the seedling to appear above ground is the hypocotyl, which emerges as an arch (Fig. 249). At the base of the hypocotyle-

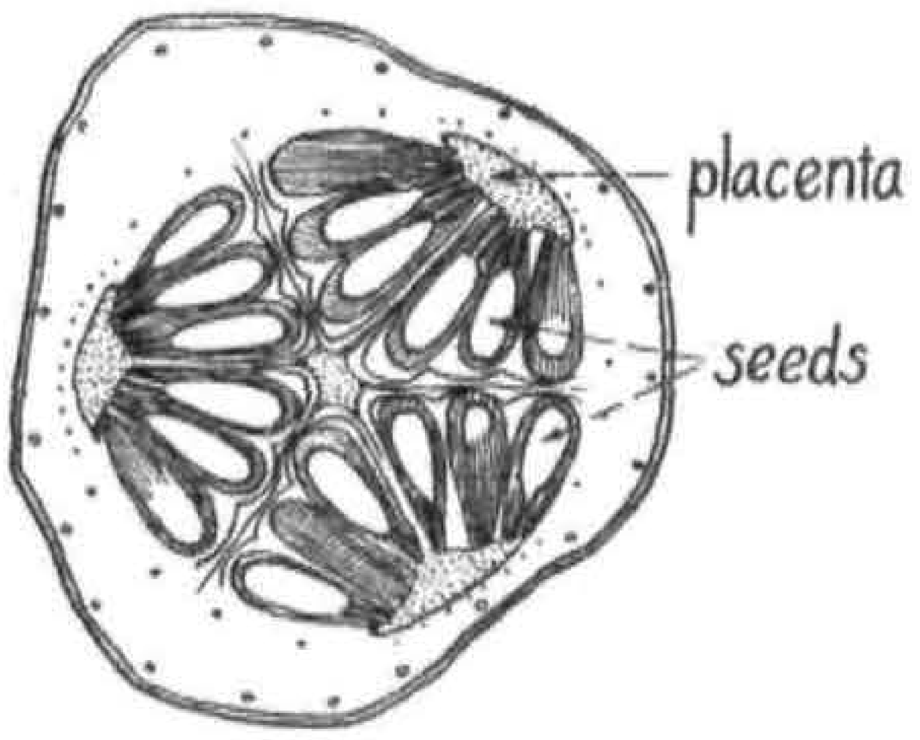


FIG. 248.—Cross-section of mature fruit of cucumber (Cucumis sativus).

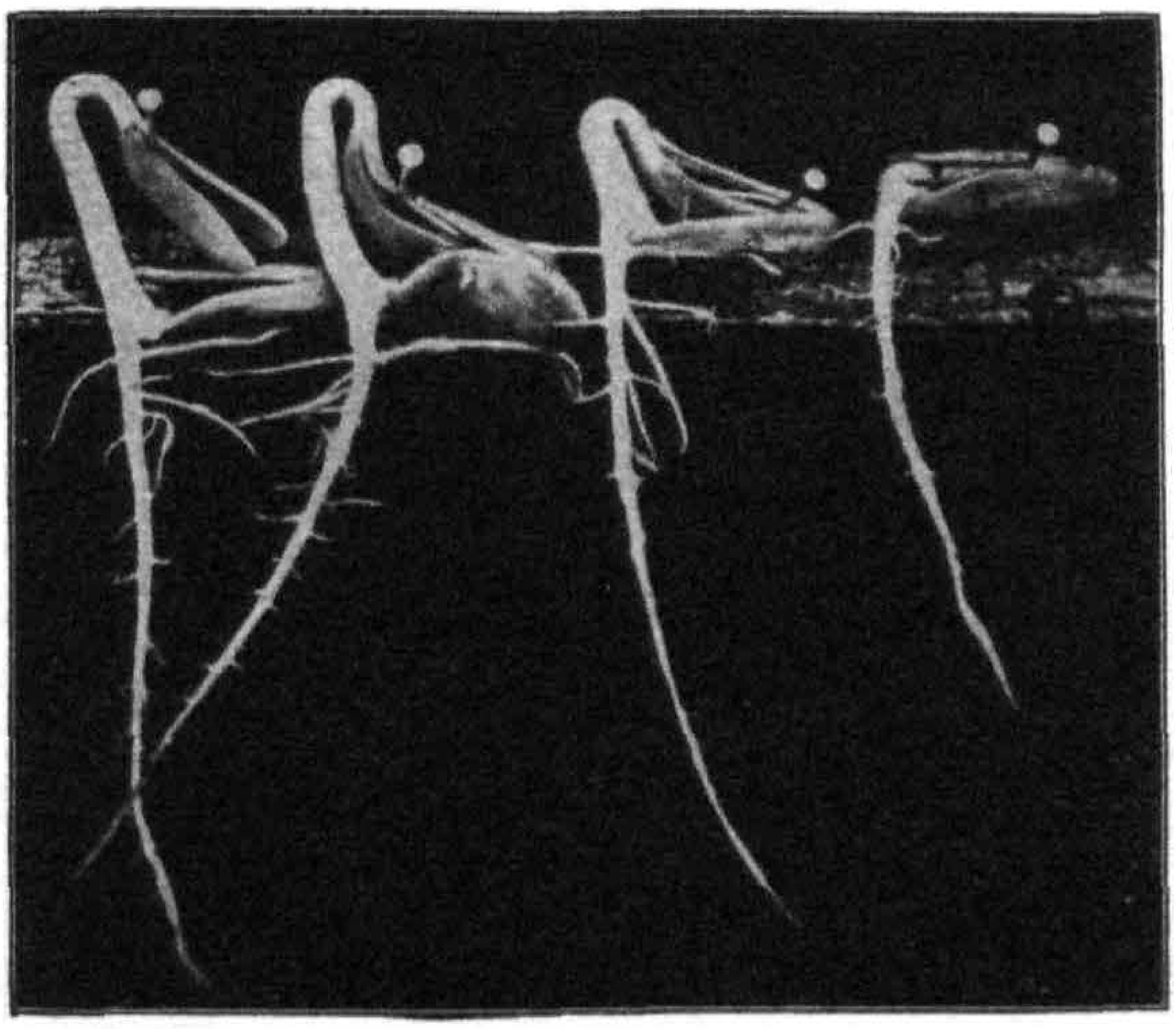


FIG. 249.—Germination of pumpkin (Big Tom) seeds, showing the pegs functioning in the removal of the coats. (*After Crocker, Knight and Roberts.*)

donary arch, there is developed a peculiar outgrowth known as the "*peg*." It is a natural part of the plant, and although it varies somewhat in size in different cucurbits, it has been shown that gravity has no direct effect in increasing peg development or in determining its lateral placement on the

hypocotyl. The peg serves to hold the seed coat while the hypocotyl withdraws the cotyledons from the coat. It will be noticed (Fig. 249) that one edge of the seed coat is caught against the peg.

KEY TO PRINCIPAL GENERA

Corolla rotate or campanulate, five-parted to or almost to the base.
  Tendrils often two to three times branched, *Citrullus* (watermelon, citron).
  Tendrils simple, *Cucumis* (muskmelon, cantaloupe, cucumber).
Corolla campanulate, five-lobed to or little below middle *Cucurbita* (gourd pumpkin, squash).

CUCURBITA (Squash, Pumpkin, Gourd)

Stems, Leaves, Flowers.—Members of this genus are annual, prostrate bushy or trailing vines with rough *stems* which have a tendency to root at the nodes. The tendency is particularly marked in the long-running varieties of squashes (Turban, Marblehead, Canada Crookneck, Field Pumpkin). The tendrils are branched. The *leaves* are usually cordate at the base, lobed (*C. pepo*), or not lobed (*C. maxima*). The *flowers* are always solitary in the axils of the leaves, yellow, and monœcious. In squashes with a bushy habit (early squashes), the staminate flowers are on long peduncles, while the pistillate flowers occur near the base of the plant on comparatively short peduncles. In the long-running squashes (fall and winter types), the staminate flowers are borne near the center of the plant on long peduncles, while the pistillate occur some distance from the roots, on comparatively short stalks. The flower stalks (peduncles) may be strongly ridged (as in *C. pepo* and *C. moschata*) or comparatively smooth (as in *C. maxima*). In the *staminate flowers*, the calyx tube and corolla are campanulate and five-lobed; the stamens are three in number, inserted on the calyx tube, the filaments are free, and the anthers large, linear, and more or less united; the ovary is rudimentary. In the *pis-*

tillate flowers, the calyx and corolla are as described above; the stamens are rudimentary (three staminodia commonly present), pistil one, ovary oblong with three to five many-

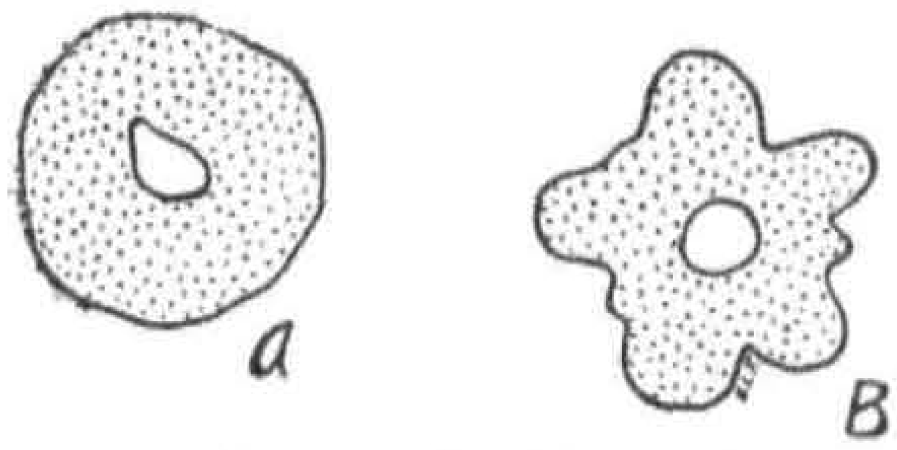


FIG. 250.—*A*, cross-section of squash (Cucurbita maxima) fruit stalk; *B*, same of pumpkin (Cucurbita pepo).

ovuled placentæ, style short and thick, and stigmas three to five, each two-lobed and papillose. There are always many more staminate flowers produced than pistillate.

Pollination and Fertilization.—The squashes and pumpkins are usually insect-pollinated. It has been shown that the varieties of *C. pepo*, including the common Crookneck, Scallop, and Pineapple squashes, and the common field

FIG. 251.—*A*, fruit stalk of Cucurbita maxima; *B*, of C. pepo; *C*, of C. moschata. (*After Bailey.*)

pumpkin, will readily cross with one another. However, the above will not cross with varieties of *C. maxima*, including Hubbard, Marblehead, Turbans, and Mammoth Chili and Valparaiso pumpkins. These latter will cross with one another. Varieties of *C. moschata* will not cross with either of the above species. *Cucurbita* species do not cross with

melons and cucumbers. Squashes and pumpkins ordinarily do not reach any considerable size unless the ovules are fertilized.

Mature Fruit.—The mature fruit is a pepo. In the Turban squashes, the receptacle does not extend over the top of the ovary, while in most other sorts, it is entirely closed at the top. The pericarp is fleshy.

Geographical.—The genus *Cucurbita* has about 10 species, natives of tropical America, Asia, and Africa.

KEY TO IMPORTANT SPECIES OF CUCURBITA

Leaves lobed; stalks of fruit strongly ridged (Fig. 250, B).
  Calyx lobes narrow, peduncle not enlarged next to the fruit (Fig. 251, B). *Cucurbita pepo* (pumpkin, scallop, gourd).
  Calyx lobes broad, peduncle much enlarged next to the fruit (Fig. 251, C), *C. moschata* (Canada Crookneck and Cushaw).
Leaves not lobed; stalks of fruit not prominently ridged (Fig. 250, A), *Cucurbita maxima* (Marblehead, Turban, Hubbard squashes, etc.)

CUCURBITA PEPO

Description.—This is an annual species, with long, running *stems;* in the so-called "bush-pumpkins," which include the scallops (patty-pans or cymblings) and summer or crookneck squashes, the plants are more compact. The *leaves* are three- to five-lobed. The calyx lobes are narrow. The peduncle is not enlarged next to the fruit. The *fruit* varies much in size and shape.

Origin.—There is a question as to the origin of the pumpkin. It is considered by some to be of American origin, as it was cultivated by the Indians at the time America was discovered. However, it is claimed by others that its original home is southern Asia.

Types and Varieties.—*Cucurbita pepo* includes the following groups:

Plants with long, running stems, *True field pumpkins* (Connecticut field and Mammoth are common varieties).

Some of the vegetable marrows have long, running stems, while others have a bushy habit. As a group they are relatively unimportant.

Plants bushy, *Summer squashes, crooknecks.* In these the neck is decidedly crooked and narrow, the distal end is swollen but terminating in a point, the skin is orange-colored and covered with many round excrescences.

Scallop or patty-pan varieties. These are also known as custard marrows, and in the South as cymblings. The leaves are large, entire, and very slightly five-lobed; the fruit is much broader than long, the edge coarsely scalloped; the flesh is solid and floury; the skin is smooth and of various colors. The pineapple summer squashes are oblong-conical varieties.

Plants with slender, running stems; leaves lobed; fruit small, hard, not edible, of various shapes, *Gourds* (in part) (*C. pepo* var. *ovifera*).

Not all "gourds" belong to the species *Cucurbita pepo.* In addition to this species, they are also referred to *Lagenaria vulgaris, Luffa, Cucumis dipsaceus, Cucumis anguria,* and *Benincasa cerifera.*

CUCURBITA MAXIMA

Description.—This is an annual plant with long, running, cylindrical, somewhat prickly (not spiny) and hairy *stems.* The *leaves* are large, not lobed, except on young shoots. The peduncles are smooth, *i.e.*, not ridged. The calyx tube is not ribbed. The corolla tube is of equal diameter throughout, the lobes curved outward. The *fruit* varies in shape and size, but unlike representatives of the preceding species, it never has a light color or a crookneck or bears warty excrescences; the peduncle is not much enlarged next to the fruit.

It is quite agreed that this species is of American origin.

Type and Varieties.—Representatives of the species *C. maxima* are late maturing, as a rule, and hence are quite generally known as "winter squashes." The principal types are as follows:

1. *Turban Squashes.*—The fruit has the appearance of a turban. This is due to the failure of the fleshy receptacle

to completely cover over the ovary, and hence the latter protrudes, forming a fruit the character of which suggests the expression "squash within squash."

2. *Hubbard Squashes.*—These are the most popular squashes in the Northern States. They are broadly pear-shaped, or olive-shaped with very thick, hard, dark green skin and dark yellow, floury flesh. There are varieties of the Hubbard (Red or Golden Hubbard) with orange-red skin.

3. *Marblehead Squashes.*—These have a gray skin. Otherwise they resemble the Hubbard squashes.

4. *Marrow Squashes.*—There are a number of varieties of these, only a few of which are very well known. Most of them have a smooth skin and a very floury flesh. The Boston Marrow, a variety with orange-colored skin and flesh, is the best known in the United States.

5. *Mammoth Pumpkins and Squashes.*—These are the largest of the squashes. Some varieties (Mammoth Whale squash, Valparaiso squash, Mammoth pumpkin) attain a diameter of 1 to 2 feet and a weight of 100 to 200 pounds. The Mammoth pumpkins are strongly flattened at the ends, while the mammoth squashes are longer than broad, and oblong or narrowly oval in shape.

CUCURBITA MOSCHATA

Description.—This is an annual with long, running, hairy (never spiny) *stems* which readily root at the nodes. The *leaves* are lobed, dark green and with whitish blotches here and there. It is said that these whitish areas are due to a thin layer of air beneath the epidermis. The calyx is deeply lobed. The corolla widens upward. The peduncle is angular, deeply ridged, and swollen where it joins the fruit. The flesh of the *fruit* usually has a musky flavor.

The species is said to have originated in Eastern Asia.

Types.—The principal types belonging to this species are:

1. *Canada Crookneck or Winter Gourd.*—The plants are small; the fruit is also rather small, smooth and crook-necked.

2. *Cushaw.*—This is the "pie pumpkin" or squash of the South and Southwest. It is a crook-necked type of squash, the skin of which may be white, yellow, of striped.

CUCUMIS (Muskmelon, Cantaloupe, Cucumber)

Stems, Leaves, Flowers.—All of our common species are hispid or rough, trailing, annual herbs. The tendrils are

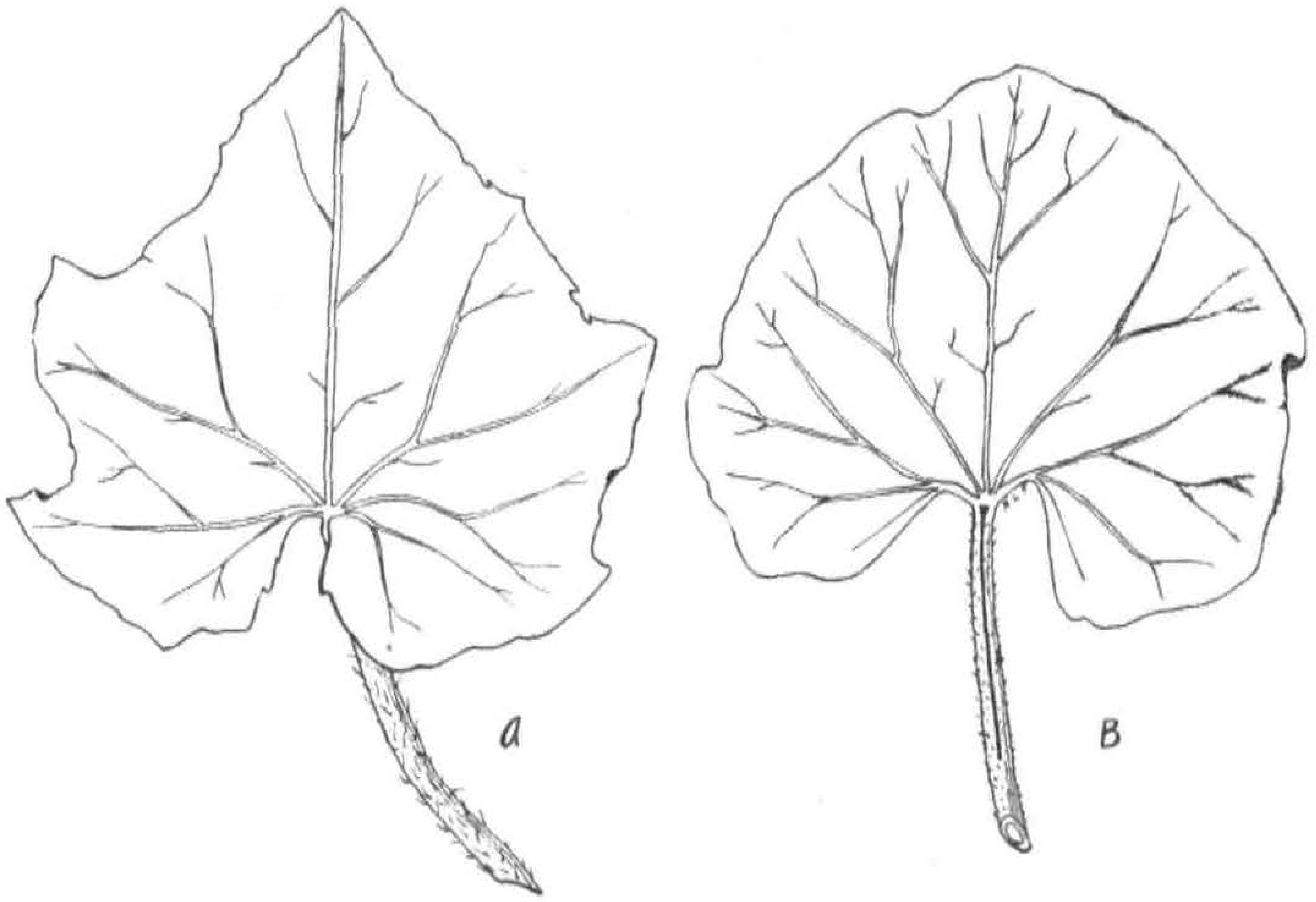


FIG. 252.—Leaves of *A*, cucumber (Cucumis sativus) and *B*. muskmelon (Cucumis melo). × ½.

simple. The *leaves* are simple, palmately three- to five-lobed or dissected. The *flowers* are monœcious. It is found that some varieties of muskmelons possess perfect flowers. For example, out of 95 varieties examined, 85 had perfect flowers, and only 11 had imperfect flowers.

The *staminate flowers* are in small clusters, or rarely solitary. The calyx tube is turbinate or campanulate, and its

limb five-lobed. The corolla is campanulate, deeply five-lobed or five-parted, the lobes acute. The three stamens are separate, with short filaments and oblong anthers. The ovary is rudimentary.

Pistillate flowers are solitary. The calyx and corolla are similar to those described above. The ovary is ovoid or globose, with three to five placentæ; the style is single and short, the stigmas obtuse, three in number, and the ovules numerous. The fruit is a pepo varying in shape, size, surface characters, and physical and chemical composition.

Pollination.—Griffin gives data with reference to pollination and fruiting of the cantaloupe. He kept an account of the number of flowers produced on each of six vines, from June 27 to July 13, at which latter date the vines became indistinguishable from each other. His data are as follows:

Date	Number of Flowers Staminate	Pistillate
June 27	203	1
June 30	338	11
July 3	474	28
July 7	755	95
July 10	660	87
July 13	645	31
Total	3,075	253
Average to each vine	512	42

Vines continue to bloom profusely until late in August in the locality (Rocky Ford, Colorado) where data were obtained. Here, melons may ripen that are set as late as the middle of August; it takes about six weeks for one to mature. Twenty ripe melons per vine is a good crop. In all *Cucumis* species; the staminate flowers are more numerous and appear earlier than the pistillate ones. Pollination is carried on by insects. Ordinarily, lack of fertilization causes a premature dropping of the fruit, and incomplete fertilization results in misshapen fruit.

Geographical.—There are close to 30 species of *Cucumis*, most of them belonging to tropical Asia, Africa, and the East Indies.

KEY TO PRINCIPAL SPECIES

Fruit smooth, not spiny or tuberculate at maturity, *Cucumis melo* (muskmelon, cantaloupe, melons).
Fruit spiny or tuberculate at maturity.
  Stems (cultivated) 6 to 15 feet long; fruit 6 to 12 inches long, *Cucumis sativus* (cucumber).
  Stems 3 to 6 feet long; fruit 1 to 1½ inches long, *Cucumis anguria* (prickly cucumber, West Indian gherkin, Jerusalem cucumber, gooseberry gourd).

CUCUMIS MELO (Muskmelon, Cantaloupe, Melons)

Description.—This is a hirsute or rough annual herb with prostrate *stems*. The *leaves* are subcordate, with somewhat rounded angles. The *flowers* are monœcious, or in some varieties the pistillate flowers are with stamens. The *fruit* varies in shape and size.

Cucumis melo is considered to be a native of southern Asia.

Botanical Varieties of Cucumis melo.—Naudin has monographed the species *Cucumis melo*, and according to him, it is divided into a number of botanical varieties, races, or groups which can be fertilized by each other. The principal ones are as follows:

1. *Netted Melons* (*Cucumis melo* var. *reticulatus*).—To this group belong the common muskmelons. These usually have a netted skin, sometimes almost smooth. All of them are shallow ribbed melons, the flesh of which may be green- or salmon-tinted (Jenny Lind, Emerald Green, Netted Gem, Rust Resistant Pollock, Ironclad, Montreal Nutmeg, Cosmopolitan, Ryan's Early Watters). The so-called "Rocky Ford Cantaloupes" are not true cantaloupes; the "Rocky Fords" include a number of varieties (chiefly Rust Resistant Pollock No. 25, Netted Gem), all of which are netted melons (var. *reticulatus*).

2. *Cantaloupes or Rockmelons* (*Cucumis melo* var. *cantalupensis*).—The true cantaloupes are usually deep-ribbed,

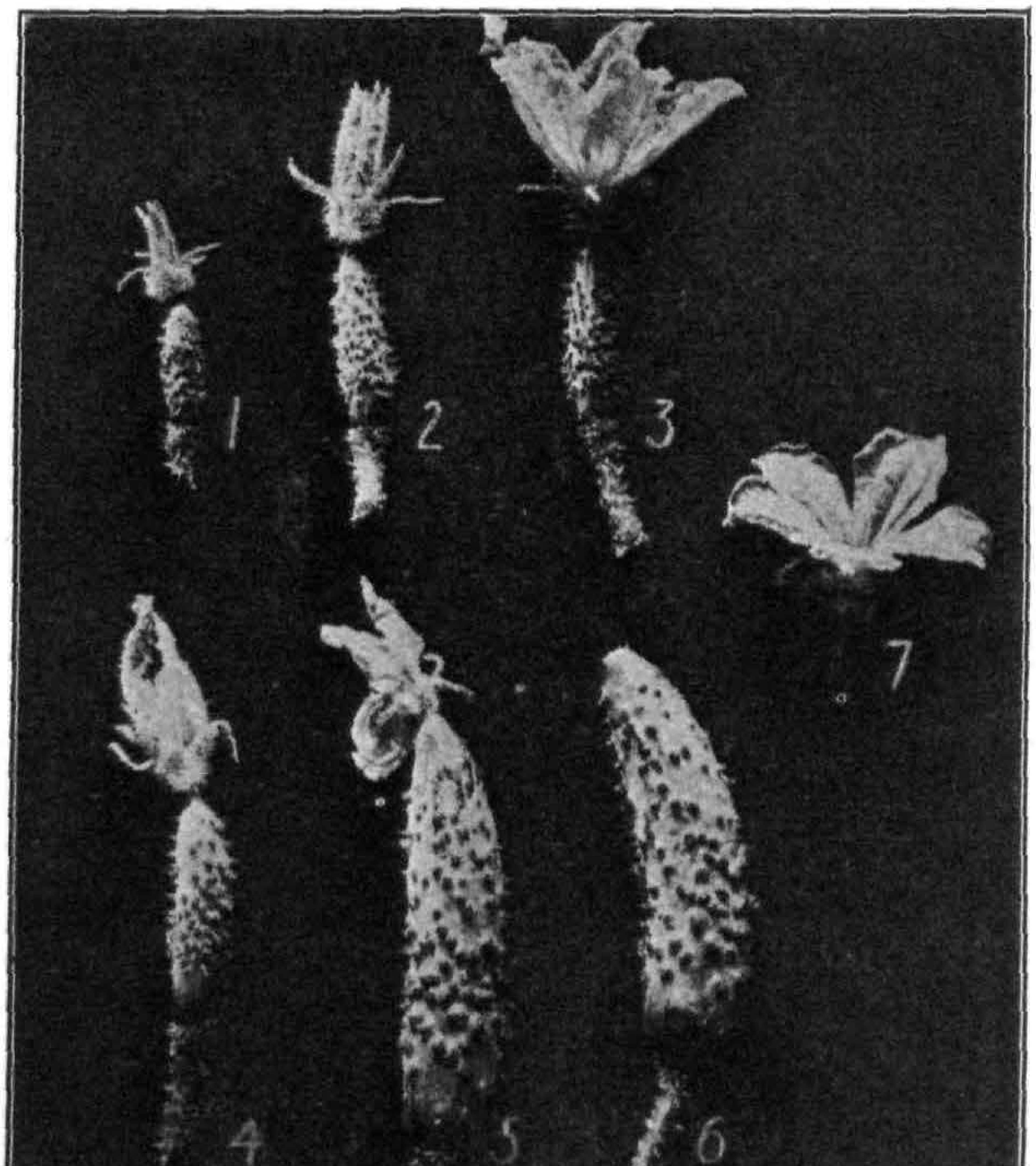


FIG. 253.—1 to 6, stages in the development of the cucumber fruit; the flower is unopen in 1 and 2, in 3 it is fully open, in 4 and 5 it is withering, and in 6 the perianth, stamens and styles have fallen from the enlarged ovary. 7, staminate flower of cucumber.

hard-rinded, and warty or scaly. The flesh is either green- or salmon-tinted (Hackensack, Nutmeg, Carmes, Long Yellow).

3. *Pineapple Melons* (*Cucumis melo* var. *saccharinus*).—These resemble the common netted melons. They are oblong in shape and have a very tender flesh.

4. *Snake Melon or Snake Cucumber* (*Cucumis melo* var. *flexuosus*).—The fruit of this is long and slender, bent and twisted, furrowed, and thickest at the distal end. It often reaches a length of 3 feet, and a diameter of 1 to 3 inches.

5. *Winter Melons* (*Cucumis melo* var. *inodorus*).—Little known in United States.

6. *Cucumber Melon* (*Cucumis melo* var. *acidulus*).—Of no economic importance.

7. *Orange Melon, Mango Melon, Melon Apple, Vine Peach, Garden Lemon, Vegetable Orange* (*Cucumis melo* var. *chito*).—Used in making preserves.

8. *Dudaim Melon, Pomegranate Melon, Queen Anne's Pocket Melon* (*Cucumis melo* var. *dudaim*).—Inedible.

CUCUMIS SATIVUS (Cucumber)

Description.—This is an annual plant with rough, hispid *stems* which reach a length of 6 to 15 feet, and are somewhat branching. The *leaves* are subcordate, almost as wide as long, and somewhat five-lobed. The corolla is yellow. There is a general impression that the cucumber can be crossed with the melon. Experiments have shown that this crossing is impossible. The fruit is oblong, obscurely three-angled, tuberculate when young, but often becoming smooth (in cultivated forms) at maturity.

Geographical.—Cucumbers have been in cultivation for 3,000 or 4,000 years. They were first cultivated in Asia. The species has not been found growing wild.

Closely Related Forms.—There are a number of "cucumbers" which may be confused (at least in name) with the common cucumber (*Cucumis sativus*). Chief of these are

the snake cucumber (*Cucumis melo* var. *flexuosus*), West Indian gherkin (*Cucumis anguria*), musk cucumber (*Cucumis moschata*), and star cucumber (*Sicyos angulatus*). The snake cucumber is in reality a melon. It is characterized by the long, narrow, twisted fruit. In the West Indian gherkin the stems are shorter and the fruit much smaller than those of the cucumber. It is a common practice to use young cucumbers as gherkins. The musk cucumber is also a melon. The star cucumber fruit is compressed, dry and membranous, and occurs in head-like clusters.

Types.—There are three principal types of cucumbers (*Cucumis sativus*):(1) *Common field cucumbers;* (2) *English* or *forcing cucumbers* (var. *anglicus*); and (3) *Sikkim cucumbers* (var, Sikkimensis). The field cucumbers are divided into black spine varieties and white spine varieties, and these two divisions are further subdivided.

The English or forcing cucumbers differ from the ordinary cucumbers. In the forcing-house, the former do not need artificial fertilization, while all our common cucumbers must be artificially fertilized. Hence, the English cucumbers have the habit of producing seedless fruit. The fruit of the forcing cucumber is long and smooth, green in color, and at first covered with a few black spines. Common varieties are Telegraph, Sion House, Kenyon, and Lorne. The Sikkim cucumber fruit is large and reddish brown, marked with yellow.

Pickles.—The growing of cucumbers for pickling is an industry quite different from that having to do with the cultivation of cucumbers for slicing. The pickle industry is mostly restricted to the Northern States, as cucumbers for this industry do best in the cooler climate of the north. Cucumbers that are to be pickled are harvested before they reach maturity, and are not allowed to reach a length of more than about 5 inches. They are hauled to the local

"salting station," where they are immersed in a brine, which is contained by large wooden tanks, some with a capacity of 1,500 bushels. The pickles are kept in these tanks until ready to be bottled at the factory.

Dill pickles are made either from pickles stored in brine or from fresh cucumbers from the vine. The peculiar flavor of dill pickles is secured by adding to the brine and cucumbers, the stems, leaves, flowering heads, and seeds of dill, a member of the family Umbelliferæ, and also, sometimes, a spice made from allspice, crushed black pepper, coriander seed, and bay leaves. Some vinegar is added in the later stages of the pickling process.

CUCUMIS ANGURIA (Gherkin)

Description.—This is an annual, creeping, branching plant. The *stems* are slender, rough-hairy, and bear simple tendrils. The *leaves* are deeply sinuate-lobed. *Staminate flowers* are small, numerous, and on short peduncles, while *pistillate flowers* are on long stalks. The *fruit* is about 1½ inches long, oval, prickly, and green with whitish streaks. The flesh is thin, and the seeds form a proportionately large percentage of the fruit.

The species is native of the West India Islands.

The genuine gherkins of commerce are the fruit of *C. anguria*. Small cucumbers (*C. sativus*) are often substituted for them, however.

CITRULLUS (Watermelon, Citron, Colocynth)

Description.—*Citrullus* species are coarse, trailing herbs with branched tendrils. The *leaves* are rotund-cordate, and three- to five-lobed. The *flowers* are monœcious, and always solitary. In the *staminate flowers*, the calyx has a broad campanulate tube and a five-lobed limb, and the corolla is

five-parted to below the middle; there are three stamens with subsessile anthers, one of which is one-loculed, the other two, two-loculed. In the *pistillate flowers*, the calyx and corolla are as described above. The ovary is ovoid with three fleshy placentæ; the style is short, with three large stigmas, and ovules are numerous. The *fruit* varies widely in form and size, color and thichness of skin, flavor, etc.

Geographical.—There are two or three species of *Citrullus*, natives of the Mediterranean region, Africa, and Asia. The only one of agricultural importance is *Citrullus vulgaris*, which includes the watermelon and citron.

CITRULLUS VULGARIS (Watermelon, Citron)

Description.—The watermelon is a hairy annual with long, angular, somewhat branching *stems*, which often attain a length of 15 feet. The *leaves* are lobed. The *flowers* are pale greenish-yellow. The *fruit* varies in shape and has a firm fleshy rind and a tender watery pulp, which is usually reddish in color and sometimes purplish, yellowish or white. The skin or rind varies in thickness from ½ inch, in such varieties as White Gem, Gray Monarch, and Hoosier King, to 1 inch in the Black Spanish, Nabob, and Golden Gate. The weight of the fruit frequently reaches 23 or 25 pounds.

Geographical.—The watermelon is indigenous to tropical and South Africa. It has been cultivated for centuries; Egyptian paintings show that these peoples cultivated them.

Types and Varieties.—The varieties of *Citrullus vulgaris* may be divided into two general types:

1. *Common Watermelon.*—Flesh of fruit comparatively tender and watery.

2. *Citron.*—Flesh of fruit very firm. As compared with watermelons, the citron feels much more solid. The citron is used for making sweet pickles and preserves. It is not eaten in the raw state. The juice of the citron is added in

equal parts to that of such fruits as peaches, cherries and others whose juices will not "jell" by themselves to make them produce jelly. The citron has a large amount of pectin in the cell walls. This is the substance in fruits which causes their juice to "jell."

The citron is not to be confused with the true citron (*Citrus medica*) (see page 478).

Rane divides the varieties of watermelons into six "classes:" (1) light green (Light Icing, Gray Monarch); (2) medium green (Fordhook Early, Jackson); (3) dark green (Black Spanish, Mountain Sweet, Cannon Ball); (4) light-striped (Golden Gate, Delaware, Hoosier King, Rattlesnake, Santiago); (5) dull-striped (Price of Georgia, Orange, Triumph); and (6) mottled green (Nabob Phinney's Early). These "classes" are subdivided into "types" according to shape of fruit, and the "types" are each divided into two groups: those with light seeds, and those with dark (black or brown) seeds.

References

CORBETT, L. C.: Cucumbers. U. S. Dept. Agr. Farmers' Bull. 254: 1–30, 1906.

CROCKER, W., KNIGHT, L. S., and ROBERT, E.: The Peg of the Cucurbitaceæ. Bot. Gaz., 50: 321–339, 1910.

GRIFFIN, H. H.: The Cantaloupe. Colo. Agr. Exp. Sta. Bull. 62: 1–18, 1901.

PAMMEL, L. H.: Crossing of Cucurbits. Bull. Torrey Bot. Club, 20: 358–359, 1893.

Results of Crossing Cucurbits. Ia. Agr. Exp. Sta. Bull. 23: 906–917, 1894.

RANE, F. W.: Fertilization of the Muskmelon. Proc. Soc. Prom. Agr. Sci., 150–151, 1898.

II. Classification of Watermelons. N. H. Agr. Exp. Sta. Bull. 86: 95–107, 1901.

CHAPTER XL

COMPOSITÆ (Thistle Family)

The composite or thistle family is one of the largest of the plant kingdom, consisting of about 10,000 species in about 760 genera; it has a wide geographical distribution.

Representatives of the family are considered to be among the most complex of plants, and among Dicots, of the highest evolutionary rank. They show a combination of characters which place them high in the scale of evolution. These are: union of petals (sympetaly), inferior ovary (epigyny), seedlike fruit, pappus, united (syngenesious) anthers, head inflorescence, diclinism, and dimorphism.

Comparatively few species of this large family are of economic value. The most important are common lettuce, Jerusalem artichoke, endive, salsify, and dandelion. The following is a short list of the less important representatives of the family: yarrow (*Achillea*), *Chrysanthemum*, sage and wormwood (*Artemisia* spp.), sunflower (*Helianthus*), *Arnica*, *Aster*, goldenrod (*Solidago*), sow-thistle (*Sonchus*), *Dahlia*, marigold (*Calendula*), rabbit-brush (*Chrysothamnus*), flea-bane (*Erigeron*), everlasting (*Antennaria*), Spanish needles (*Bidens*), and thistle (*Carduus*).

This large family is made up mostly of herbaceous forms; there are a number of shrubs, however, and a few tropical tree species. Many of them, as the dandelion and lettuce, have a milky juice, while in others the sap is watery, resinous, acrid or bitter.

Leaves.—The leaves are either alternate or opposite, rarely in whorls (verticillate), and usually without stipules.

Inflorescence.—The *inflorescence* (Fig. 254, A) is a head, the flowers, usually numerous, being mounted on a common receptacle which is subtended by an *involucre*. A "sunflower" is not a single flower in the botanical sense, but a group of composite of individual flowers. The *receptacle*

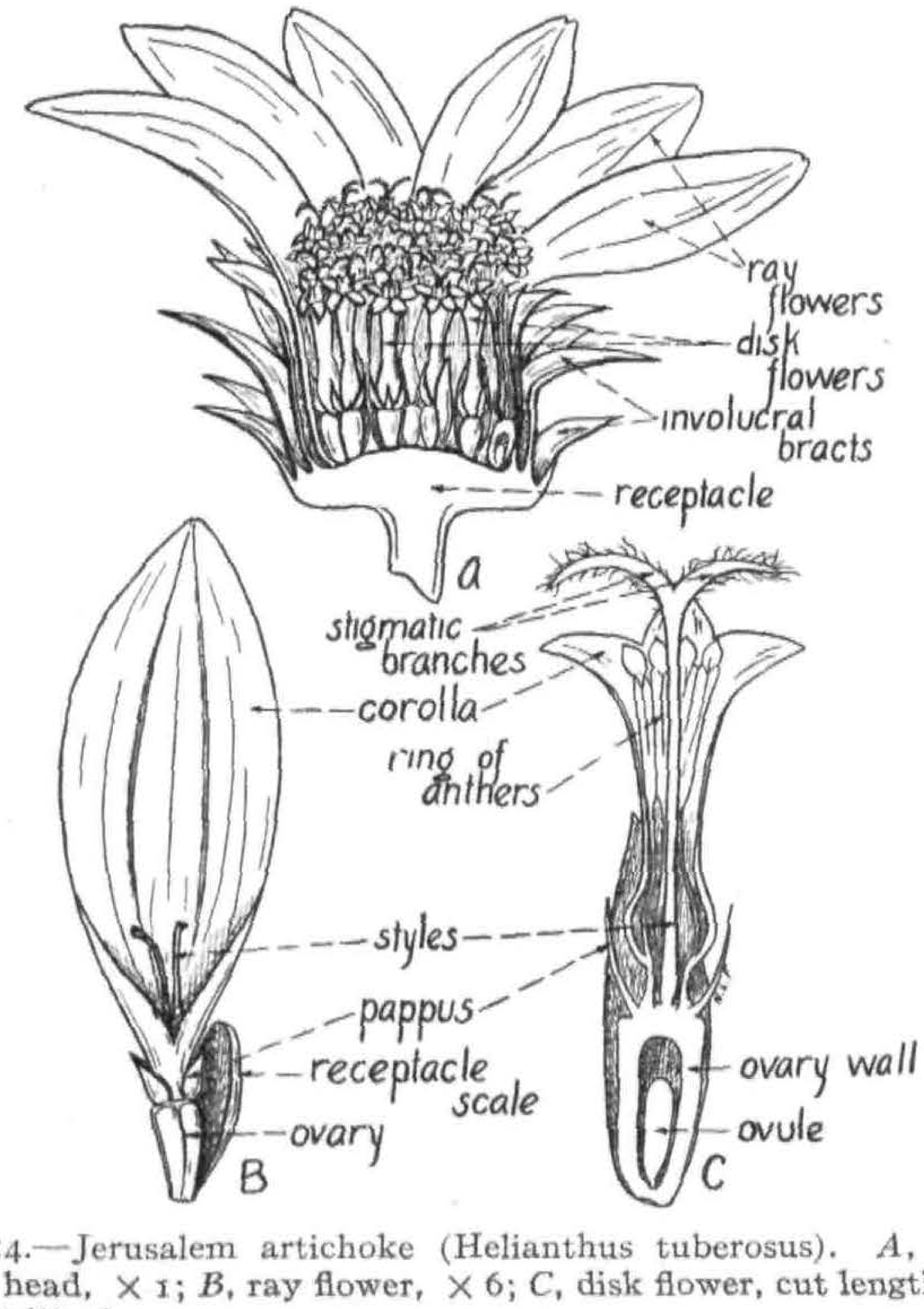


FIG. 254.—Jerusalem artichoke (Helianthus tuberosus). *A*, lengthwise section of head, × 1; *B*, ray flower, × 6; *C*, disk flower, cut lengthwise, × 6. (*A after Baillon.*)

varies in shape from flat to convex or conical. The receptacle is naked or there are chaffy scales subtending the flower; its surface is smooth, pitted, or honeycombed. The involucral bracts also vary widely in shape, from narrow and spine-like to broad and leaf-like; they occur in one or more series.

Flowers.—The *flowers* may be perfect, polygamous, monœcious or diœcious. There are two sorts of flowers in the composite family: (1) *Disk or tubular*, and (2) *ray or ligulate.*

Disk Flowers (Fig. 254, C).—These are perfect and regular and make up the so-called disk of the composite "flower." For example, the disk of the "sunflower" is the center. The *calyx* is modified, taking the form of a few or large number of bristles, awns, scales or teeth; this modified calyx is termed a *pappus*. In some instances, the pappus is entirely wanting. It is attached to the apex of the inferior ovary. The *corolla* is tubular and five-lobed. The five *stamens* are attached to the corolla and alternate with its lobes; the anthers are united into a tube. In one genus (*Kuhnia*), the anthers are distinct or nearly so. The anthers are often appendaged at the apex and sometimes caudate or sagittate at the base; pollen grains are spherical, often rough or prickly. There is a single *pistil*, an inferior one-celled and one-seeded ovary, and a single style which is entire (in sterile flowers) or two-cleft at the apex; the style branches are often tipped with appendages.

Ray or Ligulate Flowers (Fig. 254, B).—These are usually imperfect and irregular. They have a pappus and a strap-shaped corolla with either a long or short tube.

The composite family is divided into two large groups, the *Liguliflorœ* and *Tubuliflorœ*. The dandelion, chicory, and lettuce are representatives of the former, and sunflower, Jerusalem artichoke, daisy, fleabane, aster, and goldenrod typical members of the latter group. In the *Liguliflorœ*, ligulate or strap-shaped flowers are the only sort present; in these, the flowers are perfect and consist of five stamens with their anthers united into a tube, a one-celled, one-seeded ovary, a single style, and a two-lobed stigma; the pappus may be present or wanting. In the *Tubuliflorœ*, there are both

disk and ligulate flowers, the former occupying the center of the head, while the ligulate ones are at the margin of the receptacle, and are called *ray flowers*. In the *Tubilifloræ*, the ray or ligulate flowers are very frequently pistillate. In both types of flowers, the fruit (achene) is one-seeded and indehiscent. The pappus is usually persistent at the apex of the fruit, serving as a means of dissemination by the wind.

Key to Important Genera

Flowers with ligulate corollas only; flowers perfect.
- Pappus of plumose bristles, *Tragopogon* (salsify).
- Pappus not plumose.
  - Pappus of mere chaffs or these reduced and united into a crown, *Cichorium* (chicory).
  - Pappus of capillary bristles.
    - Achenes flattened, *Lactuca* (lettuce).
    - Achenes not flattened, *Taraxacum* (dandelion).

Flowers with tubular corollas or none, or only the ray flowers with ligulate corollas.
- Anthers long-tailed at the base and with long appendages at the tip; heads large; rays none, *Carduus* (thistle).
- Anthers not tailed at the base; flowers tubular only, or tubular and ligulate.
  - Receptacle naked.
    - Ray flowers yellow; involucral bracts scarcely imbricated, *Arnica.*
    - Ray flowers never yellow; involucral bracts well imbricated.
      - Bracts of involucre imbricated in several series, *Aster.*
      - Bracts of involucre in but one or two series, *Erigeron* (fleabane).
  - Receptacle chaffy.
    - Bracts of involucre foliaceous, *Helianthus* (Jerusalem artichoke and sunflower).
    - Bracts of involucre dry, thin, and papery.
      - Receptacle chaffy, *Achillea* (yarrow).
      - Receptacle not chaffy, naked, or sometimes hairy.
        - Ray flowers present, *Chrysanthemum.*
        - Ray flowers none, *Artemisia* (sage and wormwood).

LÁCTUCA SATIVA (Garden Lettuce)

Description.—Common garden lettuce is a tall, annual leafy herb, with a milky juice. There is thrown up from a short stem early in the season a cluster of leaves varying

considerably in shape, character, and color, in the different varieties. Later in the season, a "seed stalk" is sent up. Tracy found that, at Washington, D. C., the first appearance of the seed stalk after sowing seed, varied from 59 (in Emperor Forcing) to 112 (in Italian Ice) days. The *leaves* are alternate, denticulate or pinnatifid, sessile or auriculate-clasping, sometimes spinulose-margined, the lowest ones large, and the upper much smaller. The *inflorescence* is a

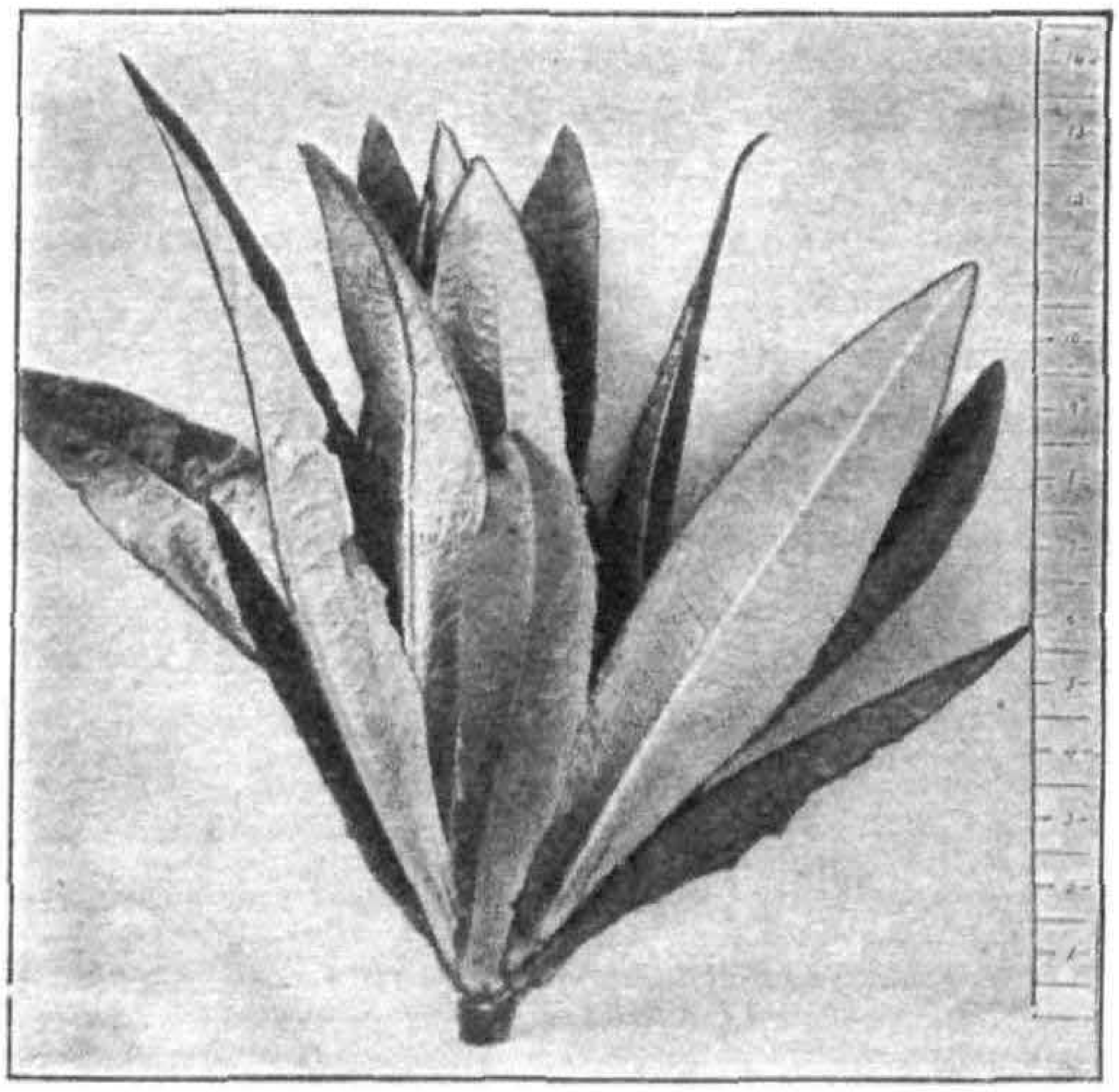


FIG. 255.—Asparagus lettuce, var. angustana. (*After Corbett.*)

panicle. The *flowers* are yellowish or yellowish-white, the involucre cylindric, the bracts of which are imbricated in several series, the outer shorter. The *receptacle* is flat and naked. The corolla rays are truncate and five-toothed at the end. The anthers are sagittate at the base. The style branches are slender. Lettuce is almost entirely self-pollinated. The pollen is shed prior to anthesis, and the stigma is covered with pollen when the flower opens. This eliminates almost entirely the possibility of cross-fertilization. The flower head opens early in the morning, closes before

noon, and does not again reopen. The *achenes* are oval, oblong, or linear, flat, three to five-ribbed on each face, narrowed above or contracted into a narrow beak which bears a large number of soft, capillary, white or brown

FIG. 256.—Cutting or cut-leafed lettuce, var. intybacea. (*After Corbett.*)

pappus bristles. The achenes vary in color; whitish, blackish, yellowish, or brownish.

Origin and Geographical.—It is quite generally conceded by botanists that out garden lettuce (*L. sativa*) is originated from the wild species, *L. scariola*. This latter species grows wild in Europe, Canary Isles, Madeira, Algeria, Abyssinia, and Eastern Asia, and has also become naturalized in the United States, where it is often a troublesome weed. In

this country, *L. scariola* is distributed from New York to Minnesota and Missouri. The close relationship between *L. sativa* and *L. scariola* is shown by the fact that they readily cross.

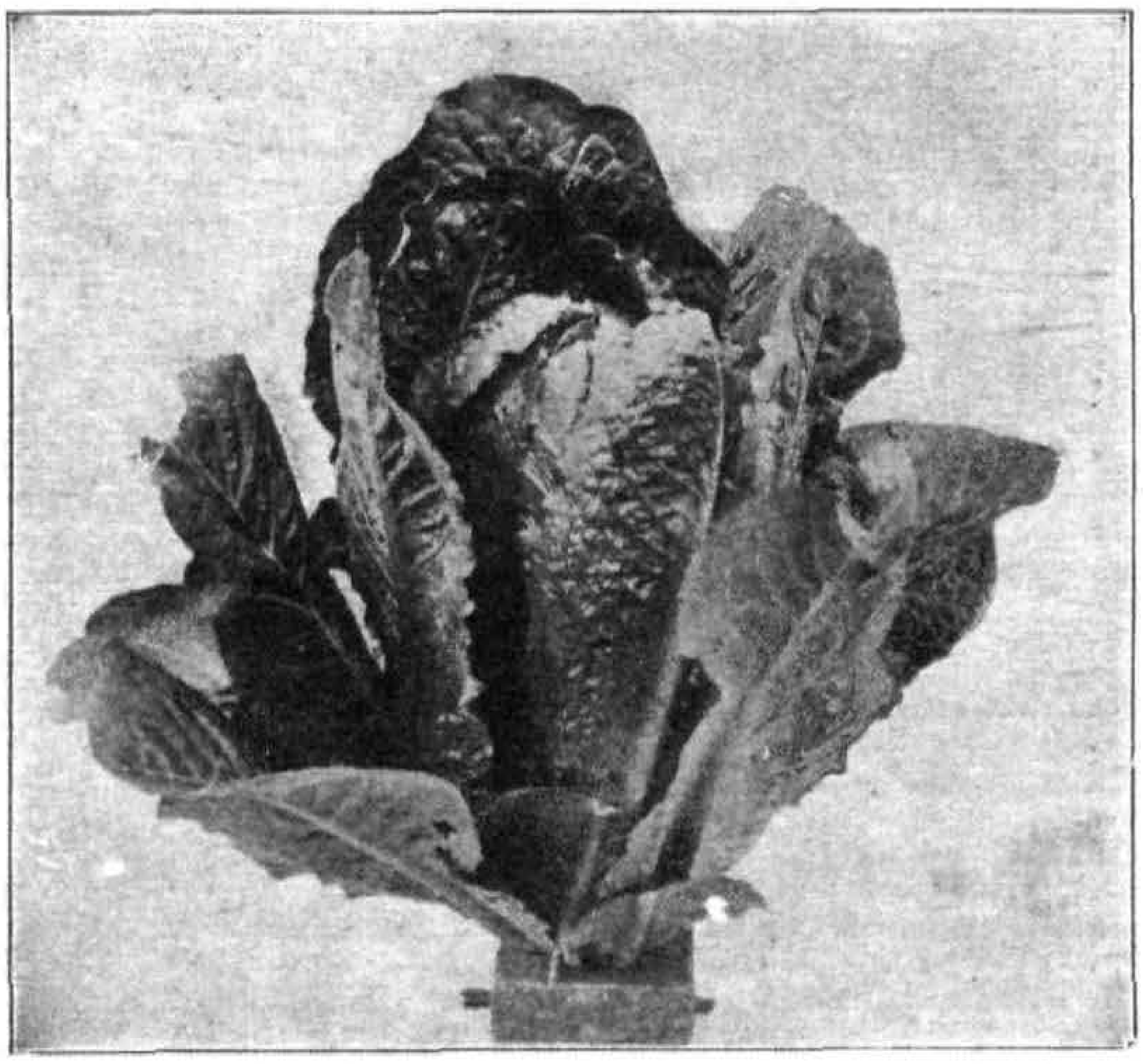


FIG. 257.—Cos lettuce, var. romana. (*After Corbett.*)

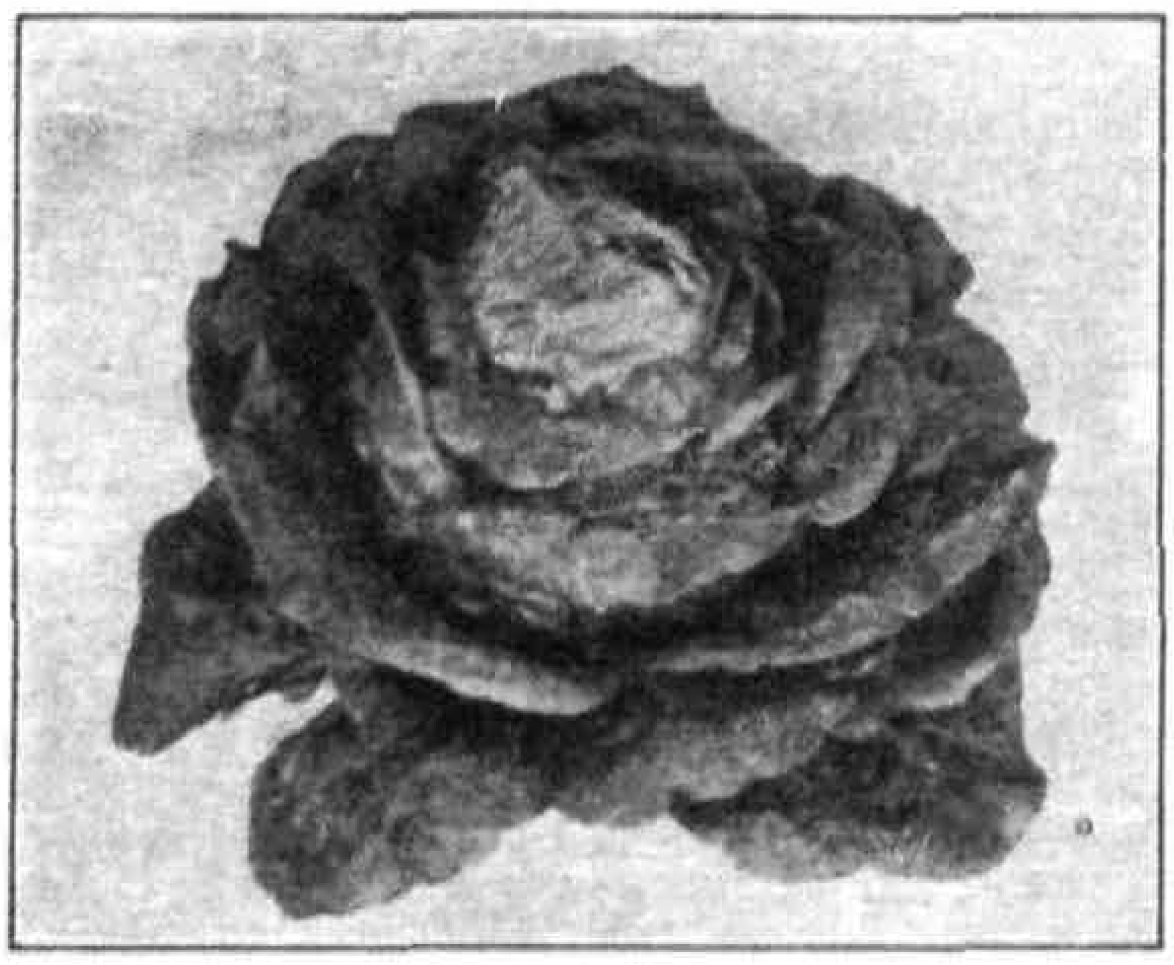


FIG. 258.—Head lettuce, var. capitata. (*After Corbett.*)

There are a number of native species of *Lactuca* in this country. Britton and Brown mention eight species native of the eastern and northern United States, besides the intro-

duced *L. scariola.* This latter species is commonly known as the "compass plant."

Lettuce has been cultivated from very early times. There are historical notes concerning its popularity as a vegetable several hundred years before the Christian Era.

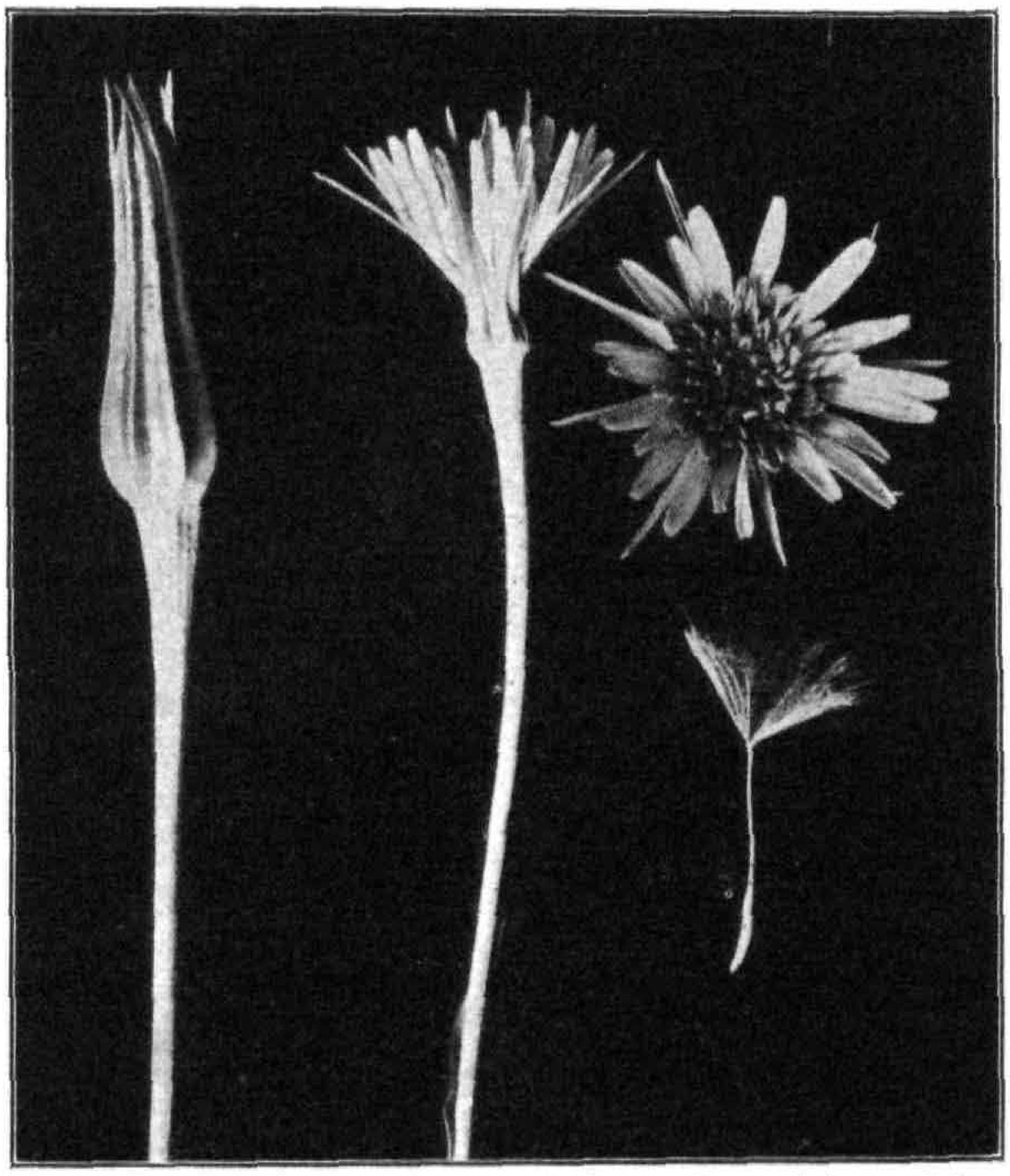


FIG. 259.—Salsify (Tragopogon porrifolius). From left to right: unopen flower head; side view and face view of open flower head; achene with pappus at tip of beak.

Types of Lettuce.—Four types or botanical varieties of cultivated lettuce are recognized. These may be distinguished by the following artificial key:

KEY TO TYPES OF LETTUCE

Basal leaves narrow, distinctly lanceolate, *L. sativa* var. *angustana* (asparagus lettuce).

Basal leaves broad, spatulate, oval to roundish, always rounded at the tip.
 Leaves deeply cut on the edges, *L. sativa* var. *intybacea* (cutting or cut-leaved lettuce).
 Leaves entire or but slightly toothed.
  Leaves forming a rather compact roundish or flattish head; leaves never decidedly stiff and flat, *L. sativa* var. *capitata* (head or cabbage lettuce).
  Leaves forming a conical or cylindrical-shaped head; leaves straight and stiff, *L. sativa* var. *romana* (cos lettuce).

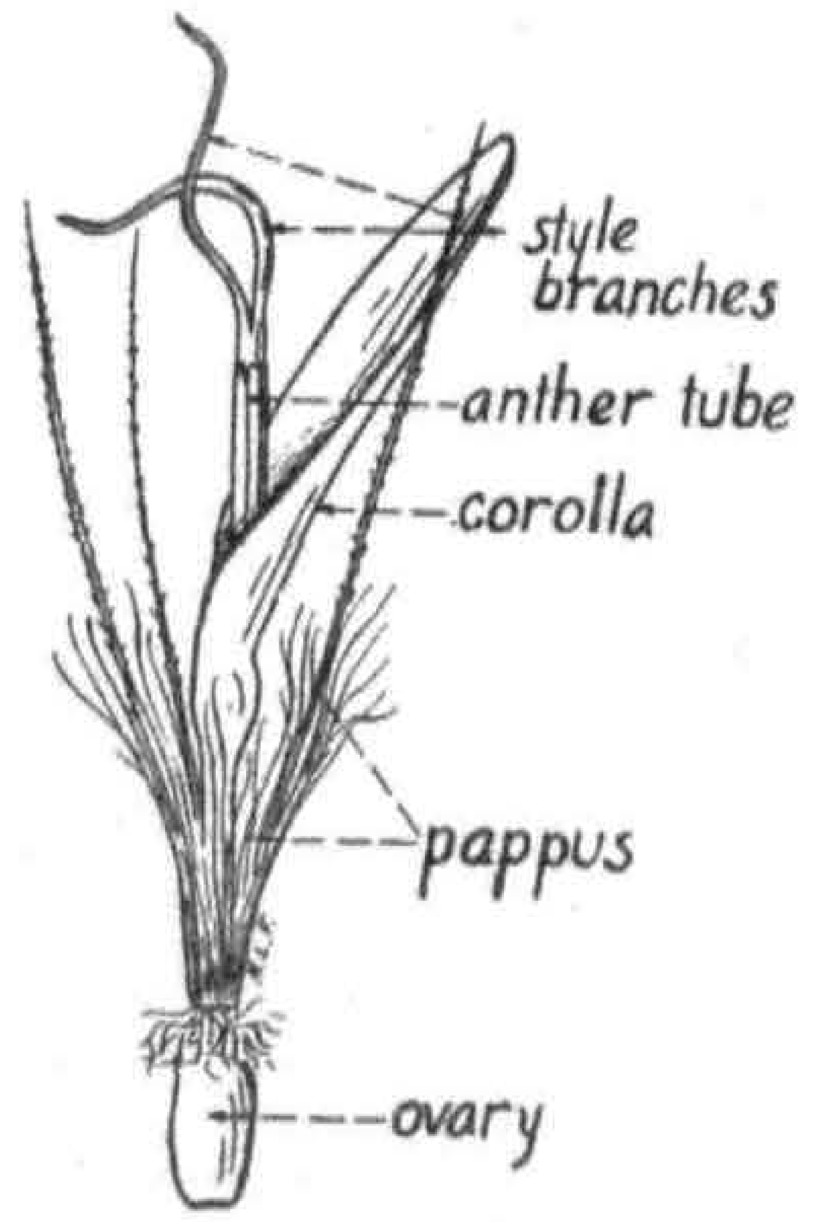


FIG. 260.—Single flower of salsify (Tragopogon porrifolius). × 2½.

Tracy classifies the American varieties of lettuce as follows: (1) butter varieties, (2) crisp varieties, and (3) cos varieties. These three groups are further subdivided.

TRAGOPOGON PORRIFOLIUS (Salsify or "Oyster Plant")

Description.—Salsify is a hardy perennial plant from a fleshy root. The *roots* are about 12 inches long with a diameter of about 2 inches at the top; the skin is grayish white. The *stems* are usually somewhat branched and succulent. When grown from seed, a seed stalk is sent up the second season to a height of 2 to 4 feet. The *leaves* are alternate, entire, linear-lanceolate, clasping at the base, and glaucous. Heads (Fig. 259) are single at the end of rather long, thickened peduncles, which are often hollow for several

inches below the head. The heads are purple and open early in the morning but usually close by noon. The *involucre* is cylindrical, the bracts nearly equal, in one series-linear-lanceolate, and usually much longer than the rays of the flowers. The corollas (Fig. 260) are truncate and five,

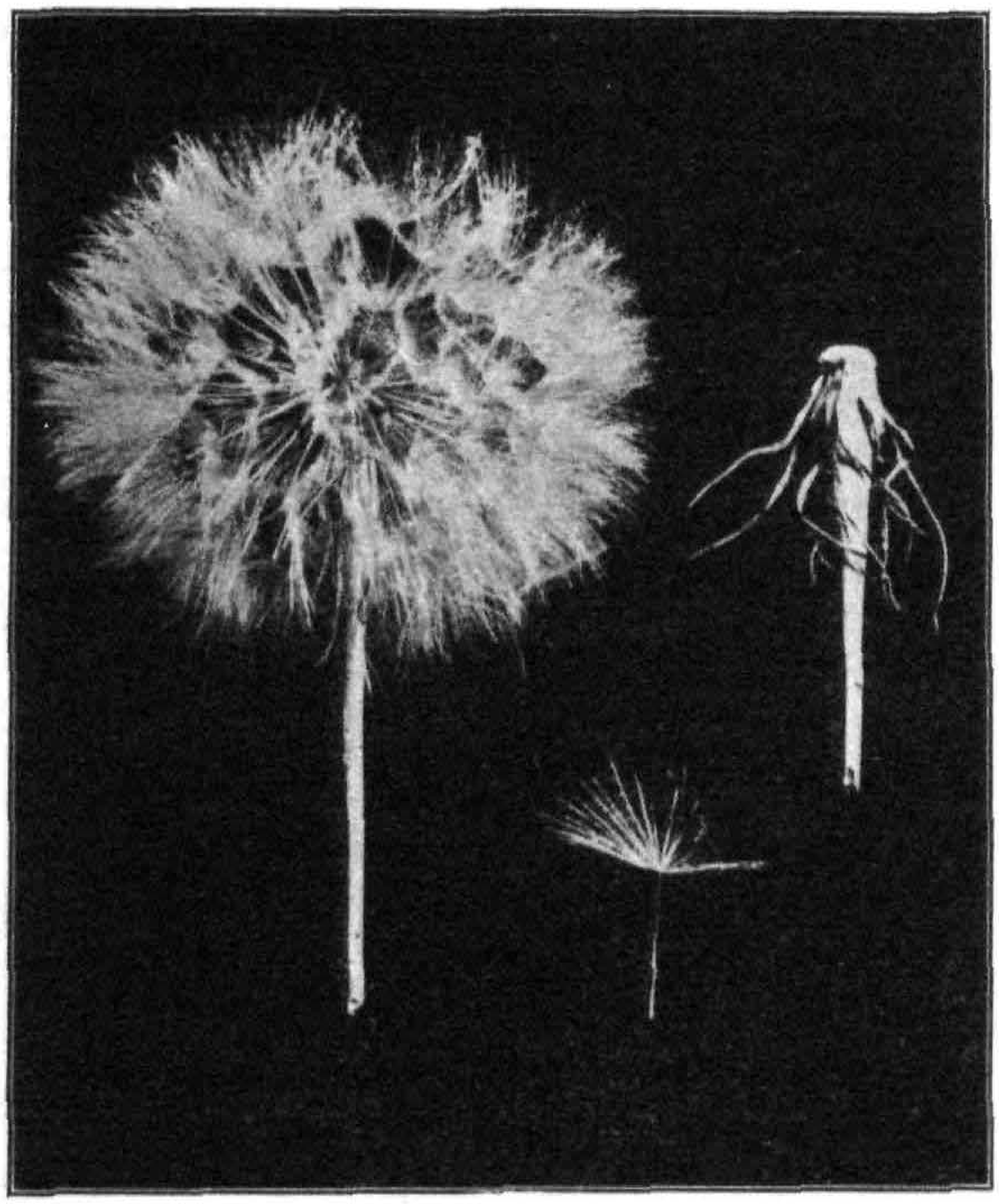


FIG. 261.—Salsify (Tragopogon porrifolius). Headin fruit; receptacle after having shed the achenes; single achene.

toothed at the apex. The *anthers* are sagittate at the base. The style branches are slender. *Achenes* are linear, and terminated by slender beaks, the outer ones being covered with tubercles, particularly on the ribs below. The pappus is grown together at the base, is plumose, and has interwebbed branches (Fig. 261).

Geographical and Closely Related Species.—The species is a native of southern Europe. It is quite widely distributed in this country in fields and waste places, probably as an escape from cultivation. A yellow-flowered salsify (*T. pratensis*), naturalized from Europe, is also quite widely distributed here. The Spanish salsify or Spanish oyster plant (*Scolymus hispanicus*), has a root much like that of common salsify, but the plant differs from common salsify in the following respects: the roots are of a lighter color and longer, the leaves prickly, and the flowers yellowish. The black salsify (*Scrozonera hispanica*), also a member of the Composite family, bears a black, fleshy, edible tap root. It differs from common salsify in that its leaves are broader, flowers yellow, and its involucral bracts are in many series.

Uses.—Salsify is grown for its fleshy roots which have somewhat the flavor of oysters, hence the common name, "oyster plant." They are used both as a cooked vegetable and as a relish.

CICHORIUM (Chicory or Succory, and Endive)

Description.—All the species of this genus are branching herbs. The *leaves* are alternate, mostly basal, the cauline ones small and bract-like. The *heads* are large, and peduncled or in sessile clusters along the branches. The bracts of the involucre are in two series, the outer spreading, the inner erect. The *receptacle* is flat, naked, or fringed with small hairs. The *corolla* rays are truncate and five-toothed at the apex. The *achenes* are five-angled or five-ribbed, truncate, and not beaked. The pappus consists of a number of short scales.

Geographical.—The species of *Cichorium* are natives of the Old World. There are two of economic importance: *Cichorium intybus* (chicory) and *Cichorium endiva* (endive).

CICHORIUM INTYBUS (Chicory or Succory)

Description (Fig. 262).—This is a perennial species from a long, deep tap root, which sends up a stiff, rough-hairy, branched *stem* to a height of 1 to 3 feet. Radical *leaves* are numerous, and spreading on the ground; the upper leaves are smaller, lanceolate or oblong, lobed or entire, clasping and auricled at the base. The *heads* are axillary. The flowers are blue or purplish, and sometimes white.

The species is a native of Europe, and has been used there from very early times as a salad plant. Mention is made of its cultivation as early as the seventeenth century. It is introduced into the United States, occurring as a ruderal from Nova Scotia to North Carolina, and west to Minnesota and Missouri.

Uses and Varieties.—The roasted root of chicory has been used as a substitute for, and an adulterant of, coffee. The young roots are sometimes boiled, and the leaves used as "greens" or served fresh as a salad. The plant is sometimes forced in the winter to produce a cluster of loose leaves for use in salads. Such clusters of leaves are called "Barbe de Capuchin." Common varieties of chicory are: Common, Large-rooted Madgebury, Long-rooted Brunswick and Improved very Large-leaved. Witloof chicory is an improved variety of Belgian origin.

CICHORIUM ENDIVA (Endive)

Description.—Endive is an annual or biennial herb with numerous *basal leaves* which vary much in character; they may be merely toothed, the teeth large or small and numerous, or pinnatifid; some of the most desirable varieties have the leaf margins very much curled. The *upper leaves* are smaller, and auricled at the base. The *stem* often rises to a height of 3 feet; it is hollow, terete, branched, and smooth or

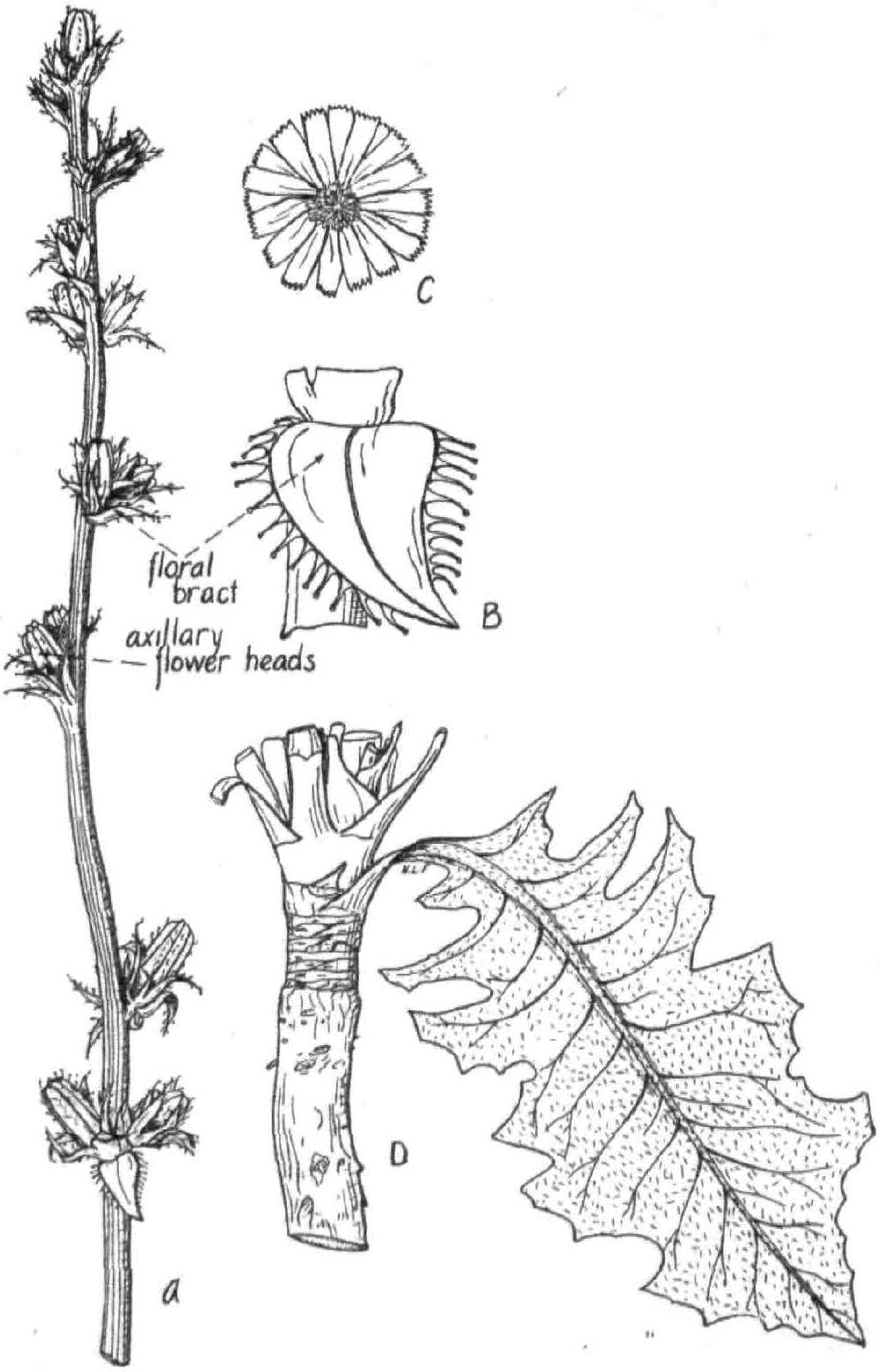


FIG. 262.—Chicory (Chicorium intybus). *A*, sessile clusters of flowers in axils of bracts, × 1; *B*, single floral bract enlarged, × 4; *C*, open flower, face view, enlarged; *D*, basal leaf, × 1½.

slightly hirsute. The *flowers* are purple and sometimes white. The *achenes* are angular and ribbed.

Geographical Distribution and Economic Uses.—Endive is a native of India. It was eaten by the early Egyptians

FIG. 263.—Tubers of Jerusalem artichoke (Helianthus tuberosus). (*After Vilmorin.*)

and Greeks. It is cultivated to a great extent in the gardens of European countries and to a less extent in the United States. There are two distinct forms of endive, the curled and the broad-leaved. The best-known variety grown here is

the Green Curled. The plant is cultivated for the young basal leaves which are blanched and used as a salad.

HELIANTHUS TUBEROSUS (Jerusalem Artichoke)

Description.—The Jerusalem artichoke is a perennial herb arising from thick, fleshy rootstocks that bear oblong tubers (Fig. 263). The above-ground *stems* attain a height of 6 to 12 feet; they are stout, branching, terete and hirsute. The *leaves* are alternate above, opposite below, simple, ovate or ovate-oblong, firm, three-nerved at the base, narrowed, rounded, truncate or slightly heart-shaped at the base, acuminate at the apex, and long petioled. The *heads* are solitary or in corymbs. Tubular (disk) and ligulate (ray) flowers are both present; the rays are yellow and the disk is also yellow (Fig. 254). The *involucre* is hemispheric, with lanceolate, acuminate hirsute or ciliate, squarrose bracts. There are 12 to 20 rays. The receptacle is chaffy; the chaff subtends the disk flowers. The *achenes* are thick, somewhat four-angled, and pubescent. The *pappus* consists of two deciduous scales.

Geographical.—The Jerusalem artichoke (also called Earth Apple, Canada Potato, Girasole and Topinambour) is native to this country and is found from New Brunswick and Ontario to Georgia and Arkansas, west and north to Canada. It was cultivated by certain American Indians. It is grown as a crop more in Europe than in America.

Closely Related Species.—The Jerusalem artichoke is closely related to the "globe artichoke" (*Cynara scolymus*) which in fact belongs to the same family, Compositæ. *Cynara scolymus* is sometimes cultivated for the flower heads and leaves. The thick receptacle together with the fleshy bases of the scales of the involucre is used as a vegetable. The plant may be distinguished further from Jerusalem artichoke by its blue or violet-purple flowers, and its large, woolly, pinnatifid leaves.

Uses.—The tubers of Jerusalem artichoke are used both as a vegetable and as a food for stock. Hogs are turned into the field and permitted to root the tubers from the ground.

References

TRACY, W. W.: American Varieties of Lettuce. U. S. Dept. Agr. Bur. Plant Ind. Bull. 69: 1–103, 1905.

GLOSSARY

Abaxile.—Situated off the axis.

Abortive.—Imperfectly formed or rudimentary.

Acaulescent.—Without an obvious stem.

Accumbent (cotyledons).—Their edges against the hypocotyl.

Achene (akene).—A one-celled, dry, indehiscent fruit in which the testa and pericarp are not firmly attached.

Acropetal.—Developing from the outside (below) toward the inside (above).

Actinomorphic.—Regular, ray-shaped; said of a flower when it can be divided into symmetrical halves by radial planes.

Acuminate.—Taper-pointed.

Acute.—Merely sharp-pointed, or ending in a point less than a right angle.

Adnate.—Grown fast to; applied to the growing together of unlike parts.

Adventitious.—Out of the ordinary place, as applied to buds or roots.

Aestivation.—The arrangement of parts in the bud.

Alliaceous.—With odor and taste of onions and garlic.

Alternate (buds, flower parts, leaves, etc.).—One after another singly at the nodes.

Ament.—Scaly unisexual spike of flowers.

Amphitropous (ovules).—Half-inverted and straight, with the hilum about the middle, and micropyle terminal.

Anatropous (ovules).—Inverted, straight and with micropyle next the hilum.

Andrœcium.—The stamens collectively.

Annual (plant).—Produces flowers, fruit, and seed the same year it is raised from seed, and then dies. Winter annuals germinate in autumn, and produce seed the following spring or summer.

Annular.—Forming a ring or circle, as embryo of beet.

Apetalous.—Without petals, as in buckwheat, etc.

Apical.—At the tip or apex.

Apocarpy.—Condition in which the carpels are separate.

Apopetaly.—Condition in which petals are separate and distinct.

Articulated.—Jointed.

Auricle.—Ear-like structure.

Auriculate.—Eared; furnished with ear-like appendages.

Autogamy.—Pollination in which pollen is transferred from the anthers to the stigma of the same flower.

Awn.—Bristle-like structure, or beard.

Awned.—Furnished with an awn or beard.

Axillary (buds, etc.).—In the axil.

Basal.—Belonging to or attached to the base.

Berry.—A fleshy fruit, with mesocarp and endocarp fleshy throughout, and seeds imbedded therein, as grape, currant, etc.

Biennial.—Of two years' duration; the first year from seed, the second year flowering and fruiting, then dying; as in sugar beet, carrot, etc.

Bipinnate (leaf).—Twice pinnate.

Blade.—Expanded portion of a leaf.

Bloom.—The whitish, powdery, and waxy secretion of epidermal cells.

Bract.—A reduced scale-like leaf, above the regular foliage leaves.

Bracteclate.—Bearing bractlets.

Bracteole.—A small bract.

Bulbils.—Small bulbs borne underground, as in garlic.

Bulblets.—Small bulbs borne above ground, as in tree onions.

Cambium.—The growing layer in the vascular bundle.

Campanulate.—Bell-shaped.

Campylotropous (ovule or seed).—Curved so as to bring the apex and base near together.

Capillary.—Hair-like in form.

Capitate.—Knob-like; shaped like a head.

Caprification.—The artificial process of pollinating figs.

Capsule (pod).—A dry, dehiscent fruit of two or more carpels.

Carcina.—Keel.

Carpophore.—A slender stalk to which the mericarps of the umbelliferous fruit are attached.

Caryopsis.—Synonym of grain—a dry, indehiscent one-seeded fruit in which the pericarp and testa closely adhere.

Catkin.—Ament. Scaly spike of flowers.

Caudate.—Tailed; with a slender tail-like appendage.

Cauliflorus.—Stem-flowering; trunks bearing flowers, as in figs.

Cauline.—Pertaining or belonging to the stem.

Chasmogamy.—Flowers that regularly open are said to show chasmogamy.

Ciliate.—Fringed with marginal hairs.

Cladophyll.—A leaf-like branch.

Claw.—The narrow or stalk-like base of some petals.

Cleft.—Cut about halfway to midrib or median line.

Coleoptile.—Leaf sheath in grasses.

Coleorhiza.—A sheath about the root.

Commissure.—The contiguous surfaces of two carpels, as in the fruit of Umbelliferæ.

Conduplicate.—Folded lengthwise.

Connivent.—Overlapping or brought close together.

Convergent.—Margins touching.

Convolute.—Rolled lengthwise.

Cordate.—Heart-shaped.

Corneus.—Horny.

Corm.—The swollen, fleshy, and solid base of a stem.

Cortex.—Bark region, from epidermis to endodermis.

Corymb.—An indeterminate type of inflorescence that is flat-topped.

Corymbose.—Corymb-like.

Crenate.—Margins with rounded teeth.

Crenulate.—With very small rounded teeth; diminutive of crenate.

Culm.—The hollow stem of grasses and sedges.

Cuticle.—A thin covering of a waxy substance called cutin on the outer wall of epidermal cells.

Cyme.—A determinate type of inflorescence, in which the first flowers to open are those toward the inside.

Cymose.—Cyme-like, or bearing cymes.

Decompound.—Several times compound or divided, as in leaves of carrot.

Decumbent.—More or less prostrate, but with the tips ascending.

Decurrent (leaf).—Extending down the stem below the point of insertion.

Dehiscence.—The opening of a fruit or anther.

Dehiscent.—Splitting open.

Dentate.—Sharp-toothed; teeth directed forward.

Denticulate.—Diminutive of dentate; furnished with very small sharp teeth.

Diadelphous (stamens).—United into two sets, as in many legumes.

Diaphragm.—A dividing partition.

Dichogamy.—A condition in which stamens and pistils do not mature simultaneously.

Diclinism.—Stamens and pistils in separate flowers, as in diœcious and monœcious plants.

Digitate.—The spreading of segments like the fingers from palm of hand.

Dilated.—Expanded.

Dimorphism.—The occurrence of two distinct forms, as in flowers of buckwheat.

Diœcious.—Bearing staminate and pistillate flowers on different ind vidual plants.

Dissected.—Divided into many lobes or segments.

Distichous.—Two-ranked, as the leaves of grasses.

Divergent.—Spreading apart.

Divided.—Segmented to the midline, midvein, or base.

Dorsal.—On the back; surface of member turned away from the main axis.

Drupe.—A one-seeded, fleshy fruit in which the endocarp is stony, the mesocarp fleshy, and exocarp skin-like.

Drupelet.—A small drupe, as in raspberry.

Elliptic.—Oval, or the shape of an ellipse.

Emarginate.—Notched at the apex.

Embryo.—Young plant within the seed.

Endocarp.—Inner wall of pericarp (ovary wall).

Endosperm.—The stored food supply in a seed.

Entire.—Without divisions, lobes, or teeth; usually refers to margins of leaves, petals, and sepals.

Epicalyx.—Extra bract-like segments below the calyx in the strawberry.

Epigynous.—Ovary inferior; flower parts above the ovary or apparently growing from its tip.

Epiphyllous.—Borne on leaf surface.

Epiphyte.—Growing upon another plant, but gaining from it no nutriment

Episperm.—Testa; seed coats.

Erose.—With an irregular margin, as if chewed.

Etiolate.—To whiten, or blanch, by the exclusion of light.

Exocarp.—Outer wall of pericarp (ovary wall).

Exserted (stamens).—Extending beyond the other flower parts.

Exstipulate.—Without stipules.

Extravaginal.—Referring to branches in grasses which force their way out through the base of the leaf sheath.

Extrorse.—Turned outwards; usually referring to anthers which shed their pollen towards the outside of the flower.

Falcate.—Shaped like a scythe.

Fascicle.—Bundle or cluster.

Fertile.—Capable of bearing fruit or seed; applied to flowers with pistils or to anther with pollen.

Fertilization.—A sexual process in which two dissimilar gametes fuse.

Fibrous.—Fiber-like, usually referring to root system of many small thread-like roots.

Filament.—Thread; stalk of stamen.

Filamentous.—Thread-like.

Fimbriated.—Fringed.

Foliaceous.—Leaf-like in form and texture.

Follicle.—A dry, dehiscent fruit with one carpel which splits along the ventral suture.

Funnelform.—Funnel-shaped.

Geitonogamy.—A method of pollination in which pollen is taken from anther to stigma of another flower on same plant.

Geniculate.—Bent abruptly at an angle, like the bent knee.

Glabrous.—Smooth; without hairs, scales, or bristles.

Glandular.—Furnished with glands.

Glaucous.—Covered with a fine, waxy-like covering (bloom) which rubs off easily.

Globose.—Globe-shaped.

Globular.—Globe-shaped.

Glume.—General name for floral bract of grasses and sedges.

Gynœcium.—The carpels taken collectively.

Hastate.—Halberd-shaped; basal lobes diverging.

Head.—An indeterminate type of inflorescence in which the flowers are in a dense cluster, as in Compositæ.

Hermaphrodite (flowers).—Perfect, both stamens and pistils present.

Hyaline.—Thin and very nearly transparent.

Hypocotyl.—That portion of the embryo stem below the cotyledons.

Hypogean (cotyledons).—Remaining underground, as in the pea.

Hypogynous.—Ovary superior; flower parts attached below the ovary.

Hilum.—The scar on a seed, marking the attachment of a seed to its stalk.

Hirsute.—Covered with stiff hairs.

Homogamy.—The anthers and stigmas mature at the same time.

Imbricated.—Overlapping.

Incised.—Cut rather deeply into sharp lobes.

Included (stamens).—Not extending beyond the surrounding parts.

Incumbent (cotyledons).—With the backs against the hypocotyl.

Indehiscent.—Not splitting open.

Indigenous.—Native to the region of growth.

Inferior (ovary).—Below the other flower parts.

Inflexed.—Bent inwards.

Inflorescence.—A flower cluster.

Integument.—Skin; coat of protecting layer.

Internode.—The interval between two adjacent nodes.

Intravaginal.—Referring to branches in grasses which grow out between the leaf sheath and the culm (stem).

Introrse.—Turned inwards; usually referring to anthers which shed their pollen towards the inside of the flower.

Involucel.—A secondary involucre.

Involucellate.—Furnished with involucels.

Involucrate.—Furnished with an involucre.

Involucre.—A series of bracts that subtend an inflorescence, as in Compositæ, cotton, etc.

Irregular (flower).—One or more of the parts of a series are dissimilar.

Keel.—Ridge, like the keel of a boat.

Laciniate.—Cut into narrow, rather deep segments.
Lamella.—Plate.
Lanceolate.—Lance-shaped.
Lemma.—The bract (glume) at the base of the flower in grasses.
Lenticular.—Shaped like a double-convex lens.
Lignified.—Woody; cell walls impregnated with lignin.
Ligulate.—Strap-shaped.
Ligule.—Appendage at juncture of sheath and blade in grasses, or, strap-shaped corolla in Compositæ.
Linear.—Long and narrow, its sides nearly parallel.
Lobed.—Divided to about the middle.
Locule.—Cell cavity.
Loculicidal.—Refers to capsules which split lengthwise through the middle of each cell.
Lodicules.—Small scales (inner perianth) surrounding the ovary in grasses.
Lumen.—Cell cavity.
Lyrate.—Lyre-shaped; the end lobe of pinnatifid leaf is much larger than the rest.

Marginal.—Along the edge or margin.
Median.—Middle.
Medulla.—Pith.
Mericarp.—One-half of the fruit of Umbelliferæ.
Mesocarp.—Middle layer of pericarp (ovary wall).
Mesocotyl.—Axis between base of coleoptile and grain, in grasses.
Micropyle.—The opening between the ovule of seed coats.
Microsporangium.—Anther sac; case bearing microspores.
Monœcious.—Staminate and pistillate flowers in different inflorescences on same plant.
Mucronate.—With a sharp and abrupt point.

Nerve.—Veins or ribs in bracts, scales, petals, sepals, etc.
Node.—The point on the stem from which a leaf or leaves arise; the junction of two internodes.
Nucellus (megasporangium).—The ovule tissue within the integuments.
Nutlet.—A small nut.

Ob.—A prefix signifying inversion.
Obcordate.—Heart-shaped, with broad end at the tip.
Oblate.—Flattened at the ends.
Obovate.—Egg-shaped in outline, with the broader end at the tip.
Obsolete.—Rudimentary, or entirely absent.
Obtuse.—Blunt or rounded at the apex .
Ocreæ.—Sheathing stipules in Polygonaceæ.

Orbicular.—Approximately circular in outline.

Orthotropous (ovule).—Straight; hilum at one end and micropyle at the other.

Ovate.—Egg-shaped in outline; broader end at the base.

Ovoid.—Egg-shaped.

Ovule.—The body which becomes the seed after fertilization.

Palet (palea).—Outer perianth segment of grass flower.

Palmate.—Leaf segments or leaflets radiate from a point like the fingers from the palm of the hand.

Panicle.—A compound raceme, as in oats.

Paniculate.—Flowers in panicle or panicle-like inflorescence.

Papilla.—A small protuberance.

Papillose.—With papillæ.

Pappus.—Bristle-like, awn-like scaly structures (modified calyx) at the tip of the ovary in Compositæ.

Parenchyma.—A tissue made up of large, thin-walled cells with rather large intercellular spaces.

Parietal.—Pertaining to the wall; ovules that are attached to the wall of the ovary are said to be parietal.

Parted.—Separated into parts nearly to the base.

Parthenocarpy.—A phenomenon in which the fruit matures without fertilization of ovules.

Pedicellate.—Possessing a pedicel.

Peduncle.—A stalk, either of an individual flower or of the inflorescence.

Pendant.—Hanging.

Pentamerous (flower).—Parts in fives.

Perfect (flower).—Possessing both stamens and pistils; hermaphroditic.

Perennial.—Living from year to year.

Perianth.—Calyx and corolla taken collectively, or the external floral whorl or whorls.

Pericarp.—The ovary wall, consisting of three layers: exocarp, mesocarp, and endocarp.

Perigynous.—Calyx, corolla, and stamens borne on a rim of the receptacle such that they appear on the level with the ovary.

Perisperm.—Nucellus.

Petaloid.—Petal-like.

Petiole.—The stalk of a leaf.

Phlœm.—That portion of a vascular bundle which is largely concerned in the transport of elaborated food material.

Phyllotaxy.—The arrangement of leaves upon a stem.

Pileole.—Coleoptile (which see).

Pinnate (leaf).—Leaflets arranged along the sides of an axis.

Pinnatifid.—Pinnately cleft to the middle of the blade, or further.

Pistillate.—Bearing pistils only.

Placenta.—The membrane or surface bearing ovules.

Plicate.—Plaited.

Plumose.—Plume- or feather-like.

Plumule.—The first bud in the young plant.

Polyadelphous (stamens).—Separate, or in more than two groups.

Polygamo-diœcious.—Bearing both perfect and imperfect flowers on the same plant, with a tendency to become diœcious.

Polygamous.—Both perfect and imperfect flowers present on the same plant.

Pome.—A fruit in which the receptacle of the flower enlarges, becomes fleshy and surrounds the carpels, as in apple, pear, and quince.

Prehensile.—Adapted for holding.

Protandry.—In which the anthers of a flower shed their pollen before the stigmas are receptive.

Protogny.—In which the stigmas of a flower are receptive before its anthers shed their pollen.

Pubescence.—Fine, soft hairs.

Pubescent.—Covered with fine, soft hairs.

Raceme.—Indeterminate type of inflorescence, in which the pedicels are simple and one-flowered.

Racemose.—Raceme-like.

Rachilla.—The axis of a spikelet.

Rachis.—The axis of a spike.

Radical.—Seeming to come from the root. Leaves arising from the base of stem, close to the ground line, and said to be radical, as contrasted with those on the stem (*cauline*).

Ray.—The branch of an umbel; marginal, ligulate flowers of a composite head.

Receptacle.—The end of the axis to which the floral organs are attached; torus.

Reflexed.—Turned back.

Regular (flower).—The parts of each whorl similar.

Reniform.—Kidney-shaped.

Reticulate.—Netted.

Retrorse.—Turned back or downward.

Rhizome.—Rootstock; underground stem, usually horizontally elongated.

Rotate.—Wheel-shaped.

Ruderal.—Growing in waste places; weed.

Runner.—A prostrate, slender, above-ground stem, such as in the strawberry.

Saccate.—With a sac.

Sagittate.—Shaped like an arrow-head, with the lobes turned downward.

Salverform (sympetalous corolla).—Tubular with a spreading limb.

Scabrous.—Rough.

Scale.—Reduced leaf that appears lower on the stem than the foliage leaves

Scapose.—Bearing a nearly leafless flower stalk arising from the base of the plant.

Schizocarp.—A dry, indehiscent fruit, of two carpels, each one-seeded which split apart at maturity into two halves or mericarps.

Sclerenchymatous.—Composed of cells that fit closely together and have thick, hardened walls.

Scutellum.—Morphologically, the cotyledon of the grass embryo.

Segment.—A division of a leaf, fruit or flower.

Seminal.—Belonging to the seed.

Septum.—Partition or dividing wall.

Serrate.—With sharp teeth that point forward.

Sessile.—Sitting; without a stalk.

Sheath.—A tubular envelope about the stem, such as occurs in the leaves of grasses.

Silicle.—Similar to a silique, except that it is broader than long.

Silique.—Pod-like fruit of mustards, dehiscent, two-valved, and with two parietal placentas; longer than broad.

Sinuate.—Wavy along the margin.

Sinus.—The space between two lobes.

Spathe.—A large bract or pair of bracts, subtending a spadix or flower cluster.

Spatulate.—Shape of spatula or spoon.

Spicate.—Spike-like.

Spike.—An indeterminate type of inflorescence in which numerous sessile flowers are borne on a rachis.

Spikelet.—The unit of inflorescence in grasses and sedges; a small spike.

Spinulose.—With small spines.

Squarrose.—With spreading parts.

Staminal.—Of or pertaining to stamens.

Staminate (flowers).—Bearing stamens only.

Staminodeal.—Pertaining to staminodia, *i.e.*, abortive and sterile stamens.

Standard.—The large petal in the flowers of Leguminosæ.

Sterile.—Unproductive; without the reproductive elements.

Stipitate.—Provided with a stalk or stipe.

Stipules.—Appendages at the base of the petiole.

Stipulate.—Bearing stipules.

Stolon.—A trailing stem, above ground, that easily takes root at the nodes when it touches the ground.

Stooling.—Production of secondary branches from lowermost nodes, as in grasses; tillering.

Strobile.—Spike-like pistillate inflorescence of hop; also cone-like group of sporophylls.

Stylar.—Of or pertaining to style.

Stylopodium.—Style-foot. The nectariferous gland at the base of the style in the Umbelliferous fruit.

Sub.—Prefix signifying below, under, or almost, less than normal, in an inferior degree.

Subtend.—To grow under, or be adjacent to, as a bract subtending a flower.

Subulate.—Awl-shaped.

Sucker.—Rapidly growing shoots from roots or from stems underground.

Superior (flower).—Ovary appearing above the other parts of the flower.

Sympetaly.—Petals united.

Suture.—A line of splitting.

Sympetalous.—With the petals united to form a tube.

Syncarpy.—Condition in which the carpels are united.

Synconium.—Fleshy fruit, in which the receptacle is hollow, and its inner wall is lined with numerous flowers.

Syngenesious.—With the anthers united, as in Compositæ.

Tassel.—Staminate inflorescence in corn.

Tendril.—Slender, coiled organ used in climbing.

Terete.—Cylindrical; pencil-shaped.

Ternate.—Arranged in threes or divided into three divisions.

Testa.—Seed coat

Tillering.—Production of branches from the lowermost nodes, as in grasses.

Tomentose.—Covered with dense wool-like hair.

Tomentum.—Dense, woolly hair.

Torus.—Receptacle of a flower.

Translucent.—Partially transparent.

Trifoliate.—With three leaflets, as in clover.

Truncate.—As if cut off squarely at the tip.

Tuberculate.—Furnished with tubercles or small projections.

Tuberous.—Swollen and tuber-like.

Tubular.—Tube-shaped.

Turbinate.—Top-shaped.

Umbel.—An indeterminate type of inflorescence, in which the pedicels arise from the same point.

Umbellate.—Umbel-like.

Umbellet.—Umbel of secondary order.

Undulate.—With wavy margin.

Utricle.—A one-seeded fruit with a bladder-like covering.

Valvate (arrangement of parts in the bud).—The segments meet with their edges, without any overlapping.

Valves.—One of the pieces into which a capsule splits.

Venation.—The arrangement of veins.

Ventral.—On the lower side; surface of member turned toward the main axis.

Vernation.—Arrangement of leaves in the bud.

Versatile (anther).—Filament is attached near middle of an ther, so that it can readily turn in any direction.

Vexillum.—Standard of the flower in Leguminosæ.

Viscid.—Sticky.

Vitta (pl. vittæ).—On tubes in Umbellifer fruit.

Wing.—Lateral petal in the flower of Leguminosæ.

Whorl.—A group of organs arranged in a circle about a stem, and arising from the same node.

Zygomorphy (flower).—See Irregular.

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